BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 157

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 21, 1915.

TILLAGE AND ROTATION EXPERIMENTS AT NEPHI, UTAH.[1]

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(In cooperation with the Utah Agricultural Experiment Station.)

INTRODUCTION.

The experimental work at the Nephi (Utah) substation has been conducted cooperatively since 1907 by the Office of Cereal Investigations of the Bureau of Plant Industry and the Utah Agricultural Experiment Station. The memorandum of understanding between these two parties specifies that "the objects of these cooperative investigations shall be (1) to improve the cereals of the intermountain region by introducing or producing better varieties than those now grown, especially with regard to drought resistance, yield, quality, earliness, etc.; (2) to conduct such other experiments as might seem advisable for the accomplishment of the greatest possible good to the dry-land interests of the State." Most of the experiments which have been conducted have dealt directly with cereal investigations as specified in the first clause of the memorandum of understanding; but, as provided in clause 2 of this memorandum, a number of experiments have been carried on with methods of tillage and with minor dry-land crops.

A preliminary report of all the work at Nephi was published in 1910.[2] This report was rather general in its nature, owing to the

[1] The Nephi substation was established in 1903 by the Utah Agricultural Experiment Station. From that time until July 1, 1907, it was operated as one of several "county farms" located at various points in the State. Prof. L. A. Merrill, agronomist of the Utah station, directed the work from 1903 to 1905. Thereafter until 1907 it was under the direction of Prof. W. M. Jardine, agronomist of the Utah station. On July 1, 1907, cooperation between the Utah experiment station and the Bureau of Plant Industry was effected, and Mr. F. D. Farrell, of the U. S. Department of Agriculture, was placed in charge of the substation. He was succeeded on March 15, 1910, by Mr. P. V. Cardon. From the time of the establishment of the station until July 1, 1912, at which time he was succeeded by Mr. A. D. Ellison, Mr. Stephen Boswell was foreman. From 1907 to 1912 the State of Utah has been represented through Prof. L. A. Merrill, agronomist in charge of arid farms. On July 1, 1913, Mr. Ellison succeeded Mr. Cardon as superintendent, and Dr. F. S. Harris, agronomist of the Utah station, succeeded Prof. Merrill.

[2] Farrell, F. D. Dry-land grains in the Great Basin. U. S. Dept. Agr., Bur. Plant Indus. Cir. 61, 39 p., 2 pl., 1910.

Note.—This bulletin should be of interest to agronomists and to dry-land farmers, particularly in the Great Basin area.

fact that the experiments had been conducted during only a brief period and no conclusive results were available. In 1913 a detailed report of varietal and improvement work with cereals was issued.[1] The present bulletin presents the results of the cultivation experiments with dry-land cereals.

DESCRIPTION OF THE SUBSTATION.

A detailed description of the Nephi substation and a full discussion of the climatological data collected there were given in a previous publication;[1] hence, only a brief description of the substation will be given here, and, except in special cases, the climatological factors will not be considered further than to give general averages.

LOCATION.

The Nephi substation is located 6 miles south of Nephi, in the eastern part of Juab County, Utah, near the center of the State. It comprises 100 acres of land lying near the top of the north slope of the Levan Ridge, which transversely crosses the Juab Valley. The top of this ridge is approximately 6,000 feet above sea level and about 500 feet higher than the bottom of the valley. When the substation was located in 1903, the Levan Ridge was covered with a dense growth of sagebrush, from 2 to 5 feet in height. Now, dry farming is practiced generally on the ridge and from 150,000 to 175,000 bushels of winter wheat are produced annually in the vicinity of the substation.

SOIL.

The soil of the substation, like most soils of the Great Basin, is alluvial and very deep. It is reddish brown in color and varies in texture from clay loam to sandy loam, the latter appearing most generally beneath the 4-foot level. Above this level the soil contains about 15 per cent of clay. This comparatively high percentage of clay makes the soil "heavy" and rather difficult to work under certain conditions. In wet weather it becomes very sticky, while in extremely dry weather that on which a crop has been grown becomes very hard. The preparation of a good seed bed, however, usually is not difficult.

RAINFALL.

The average annual precipitation at the Nephi substation for 1898 to 1913, inclusive, was 13.4 inches. During this period the annual precipitation was above normal 6 years and below normal 10 years. The wettest year was 1906, with 18.48 inches precipitation; the driest year was 1910, with 9.08 inches. During the progress of the experiments reported herein, the annual precipitation was above

[1] Cardon, P. V. Cereal investigations at the Nephi substation. U. S. Dept. Agr. Bul. 30, 50 p., 9 figs., 1913.

normal in 1908 and 1909, with 16.66 and 16.19 inches, respectively; while in 1910, 1911, 1912, and 1913 it was below normal, with 9.08, 10.11, 12.61, and 12.34 inches, respectively. The average annual precipitation for these last four years was only 11.03 inches.

Most of the annual precipitation of the past 16 years has fallen during the months of March, April, and May, the latter month having the highest average. The months of June and July have been by far the driest months. A large part of the precipitation from November to March, inclusive, has fallen in the form of snow.

Most of the rainstorms at Nephi have been small and generally almost negligible. This is especially true of the storms which have occurred from March to August, inclusive. Such showers are of little value to the crops, because they fall upon a hot, dry surface and the moisture is soon lost by evaporation. It has been observed that showers of less than 0.5 inch are of little value when considered singly. When wet days follow each other consecutively, however, thus reducing the evaporation and leaving the surface soil wet, a fall of even 0.5 inch of rain is of value.

EVAPORATION.[1]

The average evaporation at Nephi during the six months from April to September, inclusive, has been about 45 inches. The lowest total evaporation, 40.53 inches, was recorded in 1909; the highest, 50.26 inches, was recorded in 1910. The lowest average daily evaporation has been recorded in April and the highest in July; however, there was little difference in the evaporation of June, July, and August.

WIND.

Strong winds or protracted hot winds are practically unknown in the vicinity of the Nephi substation, while many summer days pass without any appreciable movement in the atmosphere. When wind does blow, it is usually from the south or southwest in the morning, changing gradually during the day until by evening it is blowing from the north or northwest. The average velocity for any one day seldom reaches 10 miles an hour.

TEMPERATURE.

The highest mean and maximum monthly temperatures during the growing season have been recorded in July, while the lowest have been recorded in April and October. No records have been kept from November to March, inclusive. Comparatively low temperatures are reached in winter, sometimes as low as $-20°$ F., but serious injury to the fall-sown crops does not result if the ground is covered

[1] Instruments for measuring evaporation, wind velocity, and temperature, and the apparatus used in making soil-moisture determinations were furnished by the Biophysical Laboratory of the Bureau of Plant Industry, which is cooperating in the work at Nephi.

with snow. When there is no snow, however, winterkilling of fall-sown cereals is not uncommon.

Only two months of the year, July and August, have been free from frost. Normally, however, there are from 90 to 100 days in the frost-free period, extending from June 15 to September 15.

EXPERIMENTAL WORK.

All experiments were conducted under field conditions, the treatment differing from common farm practice only in the tillage method under test.

DESCRIPTION OF PLATS.

Rectangular tenth-acre plats were used for all experiments except one, in which fifth-acre plats were used. The tenth-acre plats were 36 by 121 feet, while the fifth-acre plats were 72 by 121 feet. The plats lay in series running north and south. The series were in pairs, the two in each pair being separated from each other by a 5-foot alley, while between the pairs of series there were roads 13 feet wide. The plats within each series were separated by 5-foot alleys. Thus, each plat was separated from the others by a 5-foot alley on two sides and one end and by a 13-foot road on the other end.

Two sets of plats were used for each experiment, except in the case of the continuous-cropping test. These two sets of plats permitted the alternate cropping and fallowing of each plat, a practice which was followed regularly.

SOIL-MOISTURE DATA.

Soil-moisture data were collected on most fallow plats and on some cropped plats. The number of samples taken varied with the plan of the experiment. Soil tubes were used in sampling, the soil being taken out in foot sections to depths of 6 to 10 feet. Each foot section was placed in a soil can, which was immediately covered with a close-fitting lid and taken soon after to the laboratory. From two to four cores were taken from each plat on each day that it was sampled.

The moist weight of each sample was obtained soon after its arrival in the laboratory. In no case was the weighing delayed more than half a day, the sampling usually being done in the forenoon and the weighing in the afternoon. After the moist weights were obtained, the samples were placed in an asbestos-board oven, where they were subjected to an average temperature of 110° C. They were left in the oven until constant weight was reached and then the dry weight of each sample was determined. The difference between the moist and the dry weights of the sample was then divided by the dry weight of the sample, to get the percentage of moisture. An average of the moisture content of all samples taken on a plat was considered the average moisture content of the plat.

TREATMENT OF THE CROP.

Methods employed.—The Turkey winter wheat (C. I. No. 2998), a hard, red variety, was used in all the experiments except where otherwise stated. Except in the tests dealing directly with seeding problems, the plats of each test were sown on the same date, at a uniform depth, and at a uniform rate (3 pecks per acre). After seeding, no cultivation was given until the following spring. Then, if deemed advisable, the plats were harrowed with a spike-tooth harrow to break the crust, which usually had formed as a result of conditions in winter and early spring. The breaking of the crust was intended to check evaporation and to stimulate the plants. One harrowing was usually all the cultivation the crops received. Occasionally, however, weeding was necessary, and when hoes were used such weeding might be considered as cultivation.

The crops were harvested with a binder, each plat being cut separately, usually when the grain was in the "hard-dough" stage. The bundles were always shocked, and then the plat was raked in order to prevent loss from fallen heads. The shocks generally stood in the field from three to four weeks before thrashing commenced.

The grain of each plat was thrashed separately. Before thrashing, the entire crop was weighed. The weight of the grain after thrashing was subtracted from the total weight of the crop, thus giving the weight of straw per plat. The weight of straw or grain, multiplied by 5 or 10, according to the size of the plat, gave the yield per acre. The acre yield of grain in pounds was then divided by the standard weight per bushel to get the yield per acre in bushels.

Sequence of operations.—The experiments here reported will be discussed in the following order, which is based upon their relation to the sequence of operations necessary to dry-land crop production: Stubble treatment after harvest, plowing, cultivation of fallow, seeding the crop, cultivation of the crop, harvesting the crop, frequency of cropping, and diversity of the crops in the rotation.

STUBBLE TREATMENT AFTER HARVEST.

In ordinary practice in this region no cultivation precedes the plowing of the plats; however, to determine the value of different methods of treating the stubble land previous to the time of plowing, two tests were inaugurated in the fall of 1911. These tests have been (1) the burning of the stubble, as compared with plowing it under; and (2) the disking of the stubble immediately after harvest, as compared with no treatment of the stubble previous to plowing. Neither of these tests has been in progress long enough to give any dependable information.

PLOWING.

In the plowing experiments at the Nephi substation comparisons have been made between spring and fall plowing; subsoiling, deep plowing, and shallow plowing; also between deep fall plowing followed by shallow spring plowing and shallow fall plowing followed by deep spring plowing. Most of the experiments have been in progress since 1908, and enough data are available to warrant a rather full discussion at this time.

Fall and Spring Plowing.

Since the test of fall and spring plowing was commenced in the fall of 1908, four tenth-acre plats have been used, thus permitting the practice of alternately cropping and fallowing the plats. The use made of each plat in each year since 1908 is shown in Table I.

Table I.—*Use of plats at the Nephi substation for the years 1908 to 1913, inclusive.*

Plat.	1908	1909	1910	1911	1912	1913
12A	Winter wheat.	Fallow	Winter wheat.	Fallow	Winter wheat.	Fallow.
13A	do	do	do	do	do	Do.
15D	Fallow	Winter wheat.	Fallow	Winter wheat.	Fallow	Winter wheat.
16D	do	do	do	do	do	Do.

From 1904 to 1908 the plats were alternately fallowed and cropped to winter wheat in the same manner indicated above. During these four years all plats received practically uniform treatment, being plowed in the fall and allowed to lie until the spring of the following year, when they were double disked and harrowed and then fallowed, with normal treatment until seeding time in the fall.

In the fall of 1908 plat 13A was plowed as usual, while plat 12A was not plowed until the spring of 1909. During the summer of 1909 the plats received uniform treatment. In the fall of 1909 plats 15D and 16D were segregated as alternates to plats 12A and 13A in this experiment. Plat 16D was plowed in the fall and left without further cultivation until the following spring. Plat 15D was plowed in the spring of 1910. Both plats were fallow during 1910 and received the same cultivation.

It will be noticed that during the last four years each of the plats in this test has been fallow two summers and has produced two crops of winter wheat, a total of four crops; that each year there have been two fallow plats and two cropped plats; that one plat of each pair has been plowed in the fall and the other in the spring; and that subsequent treatment has been as nearly the same in all cases as possible.

In studying the relative value of spring and fall plowing, moisture conservation, yield per acre, and cost of production have been used as bases of comparison.

MOISTURE CONTENT OF FALLOW.

Much of the argument in favor of fall plowing has been based upon the belief that the rough surface of fall-plowed land is in better condition than unplowed stubble land for absorbing the winter precipitation. For the purpose of determining the accuracy of this theory, soil-moisture studies were made in connection with the experiment discussed here. Soil samples were taken to a depth of 6 feet from each fallow plat at the beginning, in the middle, and at the end of the season, and the moisture content of each foot section was determined, as previously described in this bulletin. The data thus collected during the four years from 1909 to 1912, inclusive, are presented in Table II, which shows the annual and average percentages of moisture in each foot of soil and the average percentages in the first 6 feet of soil on each of the fallow plats in April, June, and September.

TABLE II.—*Annual and average percentages of moisture for each of the first 6 feet of soil in fallow plats in a test of spring plowing compared with fall plowing at the Nephi substation, samples taken in April, June, and September, for the years 1909 to 1912, inclusive.*

Season and depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Four-year average.		
	Apr. 5.	June 26.	Sept. 18.	Apr. 12.	June 24.	Sept. 1.	Apr. 17.	June 12.	Sept. 21.	Apr. 25.	June 26.	Sept. 16.	Apr.	June.	Sept.
Spring plowing:															
1 foot	20.60	15.90	17.05	21.27	12.35	11.88	20.48	15.86	13.09	14.98	14.18	12.59	19.33	14.57	13.65
2 feet	20.37	19.45	19.00	21.25	18.93	18.38	19.57	19.36	18.10	22.65	19.80	19.47	20.96	19.38	18.74
3 feet	20.10	18.80	20.45	20.50	18.70	17.65	21.02	19.09	16.93	21.88	19.70	19.55	20.87	19.07	18.64
4 feet	20.10	19.10	20.15	21.07	18.48	15.78	19.34	17.78	17.12	22.55	20.50	19.63	20.76	18.96	18.17
5 feet	18.70	19.17	19.10	21.40	20.10	16.88	17.04	16.69	15.34	22.07	20.34	17.80	19.80	19.08	17.28
6 feet	19.30	19.05	18.40	19.05	18.80	17.80	17.20	17.78	17.73	18.60	18.20	15.05	18.54	18.46	17.24
Average	19.86	18.58	19.02	20.76	17.89	16.40	19.11	17.76	16.38	20.46	18.79	17.35	20.04	18.25	17.29
Fall plowing:															
1 foot	21.10	14.60	17.65	20.93	14.45	12.83	21.29	17.98	12.26	21.55	15.82	13.29	21.22	15.71	14.01
2 feet	20.92	19.60	17.60	20.88	19.48	18.05	21.59	19.60	17.76	21.45	19.63	18.67	21.21	19.58	18.02
3 feet	20.00	19.60	19.05	20.13	18.20	17.83	20.03	17.55	17.43	19.62	18.25	18.13	19.94	18.40	18.11
4 feet	19.80	18.85	18.95	19.80	19.25	17.75	15.24	14.76	15.76	12.82	15.21	15.45	16.91	17.02	16.98
5 feet	17.97	17.90	17.75	19.10	18.55	17.05	16.13	14.79	14.95	11.39	13.30	12.40	16.15	16.13	15.54
6 feet	18.65	20.32	19.30	19.57	19.80	16.98	18.78	16.75	15.25	14.99	18.40	14.49	18.00	18.82	16.50
Average	19.74	18.48	18.38	20.07	18.29	16.75	18.85	16.90	15.57	16.97	16.77	15.41	18.90	17.61	16.53

Table II shows (1) that in every case except the second and third sampling of 1910 the average percentage of moisture in the 6 feet of soil was higher in the spring-plowed plat; (2) that the first foot of soil in the fall-plowed plat contained, as a rule, a higher percentage of moisture than the first foot of the spring-plowed plat; (3) that the slight difference in the moisture content of the second foot of the plats favored the fall-plowed plat during the spring and summer, while it favored the spring-plowed plat at seeding time in the fall;

(4) that the average moisture content of the third, fourth, and fifth feet was invariably in favor of the spring-plowed plat; (5) that there

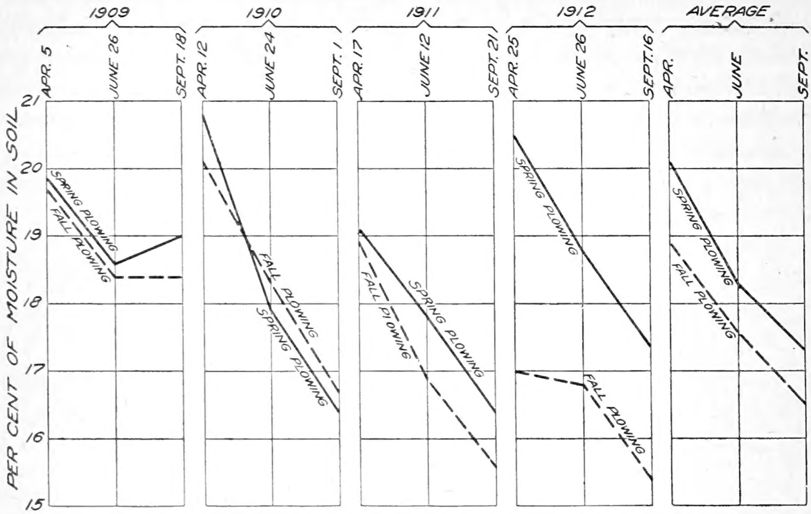

FIG. 1.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

was little difference in the moisture content of the samples of the sixth foot; and (6) that the loss of moisture from spring to fall was

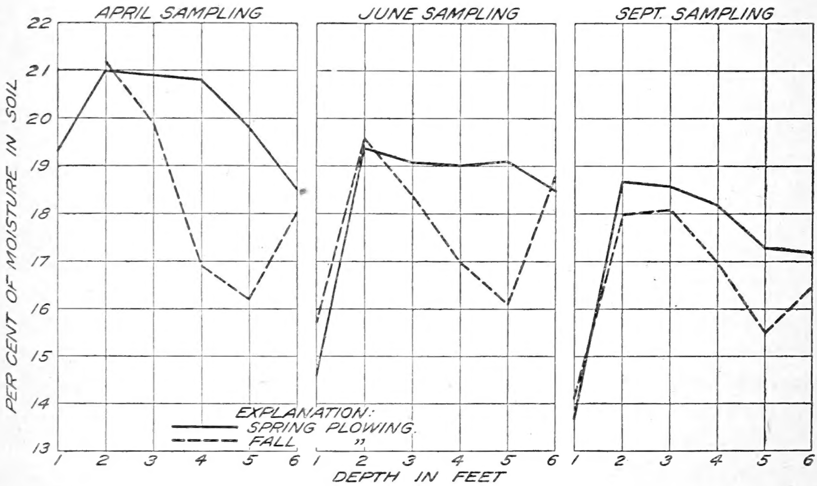

FIG. 2.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

about the same on both plats. These facts are shown graphically in figures 1, 2, and 3.

The facts thus brought out seem to indicate that at Nephi stubble land allows the winter precipitation to penetrate to greater depths than fall-plowed land and that the loose surface of the fall-plowed land retains more of the precipitation of winter than the compact surface of the stubble land. They indicate, further, that when the stubble land is plowed in the spring it loses much of the moisture in the surface foot, as does also the fall-plowed land when it is replowed or double disked, one of these operations always being necessary in the spring on fall-plowed land. This is decidedly to the disadvantage

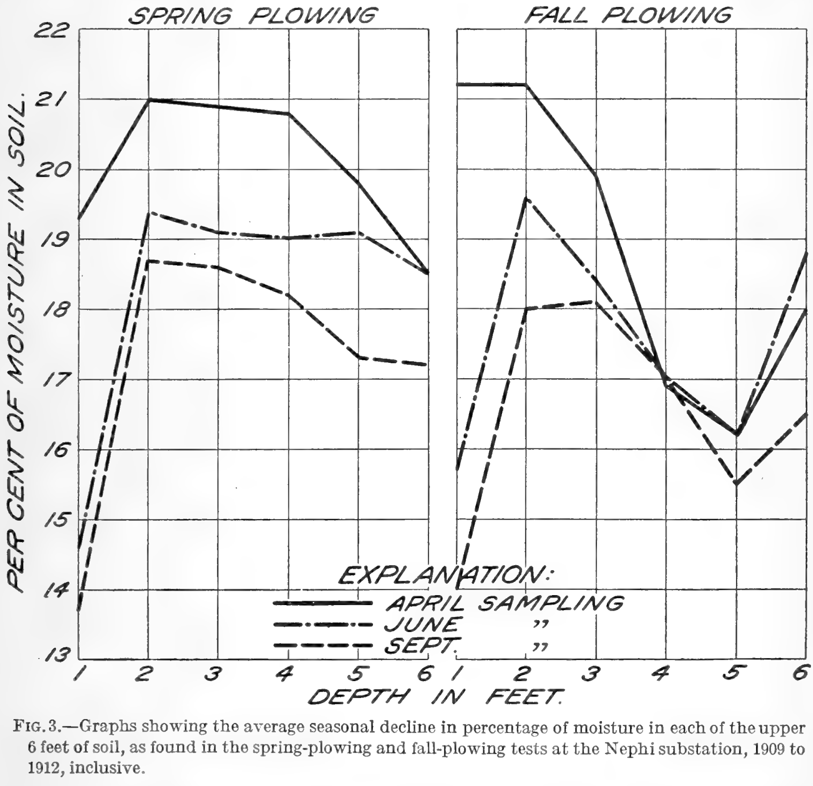

FIG. 3.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

of the fall-plowed land, which during the winter retains so much moisture in the surface foot. Lastly, the facts brought out show that the moisture content of the soil below the surface foot was practically constant throughout the season. This was favorable to the spring-plowed land, which had allowed the moisture to penetrate into the third, fourth, and fifth feet. That winter wheat makes use of moisture found at these depths is evidenced by the fact that in 1910 the roots of a winter-wheat plant growing on the station were found to extend more than 7 feet below the surface of the ground. As the spring-plowed plats had some advantage in soil-moisture content below the second foot, the higher yields on these plats were anticipated.

YIELD OF GRAIN.

The annual and average yields of winter wheat in bushels per acre from 1910 to 1913, inclusive, are presented in Table III and are compared graphically in figure 4.

TABLE III.—*Annual and average yields of winter wheat from fall-plowed and spring-plowed plats at the Nephi substation, 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Plowed in spring previous to seeding	14	33	22	5	18.5
Plowed in fall one year before seeding	12	29	22	4	16.8

The yields reported in Table III agree fairly with the moisture data reported in Table II. The average difference in yield of 1.7 bushels

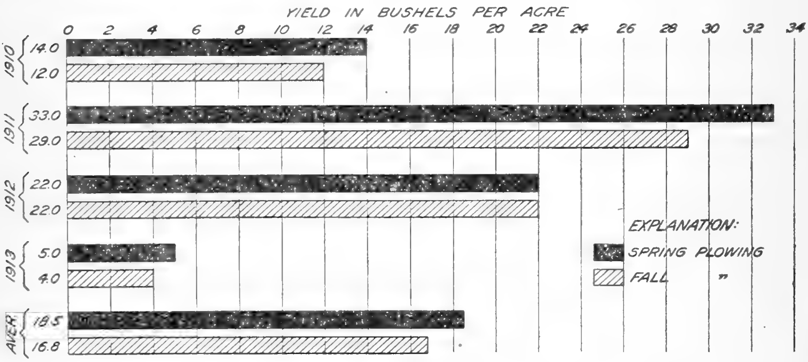

FIG. 4.—Diagram comparing the annual and average yields obtained in the spring-plowing and fall-plowing tests at the Nephi substation, 1910 to 1913, inclusive.

per acre favors spring plowing, which has given yields equal to or greater than fall plowing each year since the experiment began. This small difference in yield, however, is not so important in itself as it is when considered jointly with the cost of production.

RELATIVE COST OF FALL AND SPRING PLOWING.

Fall plowing is more difficult than spring plowing, and for this reason it generally costs more. The difference in cost at the substation has varied between 15 and 25 cents an acre, with an average of 20 cents. In addition to this, it has been observed that the plats which were spring plowed were more nearly free from weeds and volunteer grain during the fallow period than the plats plowed in the fall. It was always necessary to replow or double disk the fall-plowed plats in the spring, owing to a rather vigorous growth of weeds and volunteer grain. Even these operations often failed to destroy

all vegetative growth, so that, in order to keep the fallow clean, some weeding was necessary two or three times during the summer. It seems probable that fall plowing turns under weed seeds and grain kernels, some of which lie dormant until they are brought to the surface again the next spring by replowing or disking the land. Thus the operation which is intended to destroy all growth induces further growth by bringing other seeds into a position favorable to germination. Their growth requires frequent weeding of the fallow. These extra operations were unnecessary on the spring-plowed plats, and consequently the cost of producing crops on these plats was reduced to a point substantially below that on the fall-plowed plats.

The average cost of spring plowing was $1.93 per acre, while fall plowing cost $2.13. Replowing the fall-plowed land cost on an average $1.85 per acre, while double disking the fall-plowed land cost about 75 cents per acre, making an average cost of $1.30 and increasing the cost of fall plowing to $3.43. The subsequent weeding of the fall-plowed land cost about 25 cents per acre. This, added to the cost of plowing and replowing or double disking, makes the total cost of fall plowing $3.68, as compared with $1.93 for spring plowing, a difference of $1.75 per acre. These figures, of course, do not include the cost of cultivating the fallow, seeding and harvesting the crop, etc., which was the same on all plats and hence need not be considered here.

It has been shown that spring plowing has given an average yield of 1.7 bushels per acre more than fall plowing. The average market value of wheat at Nephi during the past four years has been 75 cents per bushel. Spring plowing, then, has yielded $1.28 more per acre than fall plowing. The extra income added to $1.75, the amount saved by spring plowing as compared with fall plowing, makes the difference in net return $3.03 per acre in favor of spring plowing.

The fact that spring plowing at the substation was done as early in the year as possible must receive emphasis at this point. The land at that time was in good condition for plowing, and it turned over in excellent shape. Later plowing was found to be less desirable. For this reason it might be advisable for farmers in distributing their farm labor to plow enough in the fall to allow them to plow all the rest of their land at the proper time in the spring. This practice is followed by many of the more successful farmers in the vicinity of Nephi.

Depth of Fall Plowing.

Previous to 1908 all of the eight plats used in the fall depth-of-plowing test were given treatment as nearly uniform as possible, being alternately fallowed and cropped to winter wheat. In the fall of 1908 four adjacent plats, 16A, 17A, 18A, and 19A, were set aside for this test. Alternate plats, 16C, 17C, 18C, and 19C, were added

in the fall of 1909. Since this time the plats have been alternately fallowed and cropped to winter wheat, receiving uniform treatment in every case except in the depth of plowing. They were replowed or double disked each year in order to destroy weeds and volunteer grain.

The depth of plowing on the different plats in the fall of 1908, 1910, and 1912 was as follows: 16A, subsoiled, 18 inches; 17A, subsoiled, 15 inches; 18A, plowed, 10 inches; 19A, plowed, 5 inches. The depth of plowing on the different plats in the fall of 1909, 1911, and 1913 was as follows: 16C, subsoiled, 18 inches; 17C, subsoiled, 15 inches; 18C, plowed, 10 inches; 19C, plowed, 5 inches.

TABLE IV.—*Annual and average percentages of moisture for each of the first 6 feet of soil in plats plowed to different depths at the Nephi substation, samples taken in April, June, and September, for the years 1909 to 1912, inclusive.*

Depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Average.		
	Apr. 6.	June 28.	Sept. 23.	Apr. 13.	June 6.	Sept. 17.	Apr. 18.	June 15.	Sept. 11.	Apr. 29.	June 28.	Sept. 16.	Apr.	June.	Sept.
SUBSOILED 18 INCHES DEEP.															
1 foot	22.00	17.37	18.05	20.35	13.13	13.05	19.50	14.83	15.95	20.99	18.89	9.68	20.71	16.06	14.18
2 feet	21.40	21.35	20.40	20.70	19.48	19.80	20.45	18.41	17.79	21.71	20.98	18.51	21.07	20.06	19.13
3 feet	21.25	19.55	19.55	20.70	19.33	16.53	15.20	16.90	18.17	18.61	19.60	17.38	18.94	18.85	17.91
4 feet	20.00	19.45	19.00	19.95	18.38	17.65	13.19	14.63	17.08	12.95	16.65	14.98	16.52	17.28	17.18
5 feet	19.05	19.50	18.65	19.15	17.83	17.83	14.72	15.51	16.30	13.35	14.64	10.48	16.57	16.87	15.82
6 feet	19.50	20.22	20.60	20.03	18.75	18.93	16.58	17.79	17.46	12.47	17.89	15.91	17.15	18.66	18.23
Average	20.53	19.57	19.38	20.15	17.82	17.30	16.61	16.35	17.12	16.68	18.11	14.49	18.49	17.96	17.07
SUBSOILED 15 INCHES DEEP.															
1 foot	21.62	18.20	18.00	20.27	14.35	14.30	20.73	16.75	18.20	26.94	16.97	13.82	22.39	16.58	16.08
2 feet	22.40	20.80	19.70	21.23	18.60	20.25	21.02	19.68	19.66	21.50	20.30	19.60	21.54	19.85	19.80
3 feet	20.65	19.60	19.75	20.57	18.78	18.40	16.70	13.47	19.50	18.85	16.57	18.37	19.14	17.11	19.01
4 feet	20.20	19.15	19.55	19.63	17.70	17.60	15.93	18.38	17.98	17.51	17.58	15.91	18.32	18.20	17.76
5 feet	18.50	18.30	18.90	17.75	17.65	17.28	14.81	15.20	15.71	12.70	13.52	13.00	15.94	16.17	16.22
6 feet	19.90	21.35	20.25	20.15	19.65	18.90	18.20	19.11	19.22	18.25	19.01	16.11	19.13	19.78	18.62
Average	20.54	19.57	19.36	19.93	17.79	17.79	17.90	17.10	18.38	19.29	17.33	16.14	19.41	17.95	17.92
PLOWED 10 INCHES DEEP.															
1 foot	21.63	16.40	17.70	20.95	14.98	15.35	20.90	17.80	16.39	22.12	18.23	13.91	21.40	16.85	15.84
2 feet	22.45	21.05	20.00	21.97	18.70	20.45	18.20	20.83	20.03	21.90	19.83	18.63	21.13	20.10	19.78
3 feet	21.45	19.80	19.65	20.82	19.25	18.68	17.84	19.89	19.63	20.40	18.64	18.09	20.13	19.40	19.01
4 feet	20.35	18.85	18.40	19.92	17.80	17.88	14.46	17.15	18.45	14.67	15.38	15.72	17.35	17.30	17.61
5 feet	20.32	18.20	15.95	20.90	18.10	17.75	15.80	16.14	17.08	11.35	13.22	13.55	17.09	16.42	16.08
6 feet	20.67	20.60	18.90	21.52	18.88	18.88	17.99	18.43	17.27	12.70	16.51	15.59	18.22	18.61	17.66
Average	21.14	19.15	18.43	21.01	17.95	18.17	17.53	18.37	18.14	17.19	16.97	15.92	19.22	18.11	17.66
PLOWED 5 INCHES DEEP.															
1 foot	21.65	15.10	17.05	20.90	15.65	14.83	20.90	17.94	17.50	22.40	18.73	15.20	21.46	16.85	16.15
2 feet	21.85	20.40	18.70	21.30	19.98	19.88	21.38	20.54	19.55	24.07	19.40	20.48	22.15	20.08	19.65
3 feet	21.20	19.35	19.00	19.08	17.30	18.50	17.48	19.17	19.44	19.07	18.22	20.17	19.21	18.51	19.28
4 feet	20.30	18.50	18.60	18.23	16.68	18.13	13.12	17.26	17.59	14.25	16.29	18.15	16.33	17.18	18.12
5 feet	19.55	17.92	18.00	19.05	18.93	19.73	14.78	15.59	17.20	16.42	17.65	18.56	17.30	17.52	18.37
6 feet	20.00	18.95	19.70	16.35	15.93	15.50	15.23	16.59	17.19	16.20	15.65	14.75	16.95	16.78	16.79
Average	20.76	18.37	18.51	19.15	17.41	17.76	17.15	17.85	18.08	18.74	17.66	17.89	18.90	17.82	18.06

It will be seen from the above that during each year since 1908 four adjacent plats, each plowed to a different depth, have been fallow and that since 1909 these four plats, with four alternates, have been cropped or fallowed. This arrangement has afforded an opportunity each year to study soil moisture on the fallow plats and yields on the cropped plats, as influenced by shallow plowing, deep plowing, and subsoiling.

MOISTURE CONTENT OF FALLOW.

All of the fallow plats of each year were sampled at the beginning, in the middle, and at the end of the season. Samples were taken to

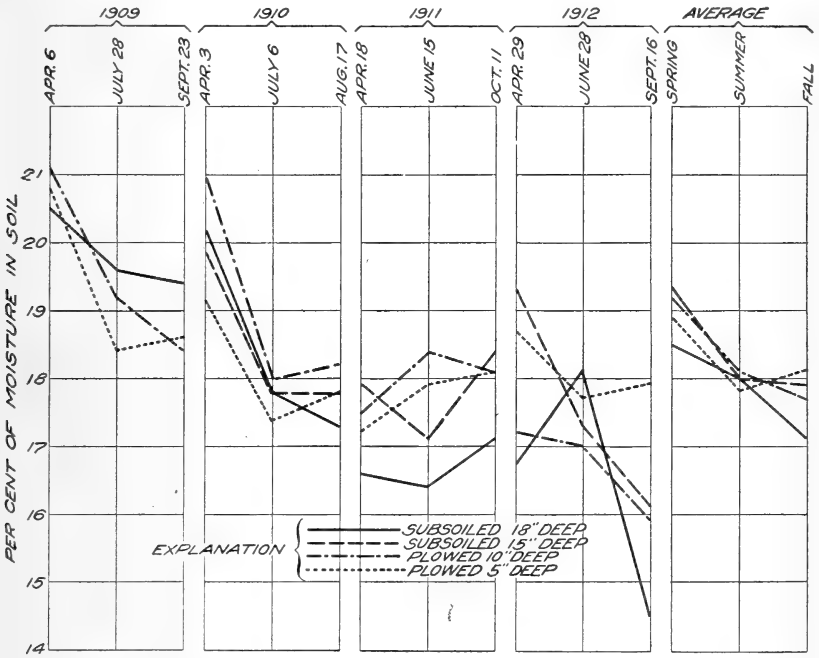

FIG. 5.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

a depth of 6 feet, and the moisture content of each foot section was determined separately. Table IV presents the data collected from 1909 to 1912, inclusive, and shows the annual and average percentage of moisture in each foot section of soil and the average of the 6-foot section in April, June, and September.

The data presented in Table IV show (1) that there was very little difference in the soil-moisture content of these plats in the spring, summer, or fall; (2) that all of the plats uniformly lost much of the moisture of the first foot during the spring cultivation necessary to rid the plats of weeds and volunteer grain and to prepare them for the fallow season; (3) that the moisture below the first foot remained

practically the same on all plats during the fallow season; and (4) that the average percentage of moisture in the fall was lower for the plats subsoiled to a depth of 18 inches than for any of the other plats. These facts are shown graphically in figures 5, 6, and 7.

The points thus brought out show that, so far as soil moisture is concerned, there was no advantage in deep plowing or subsoiling, for the moisture content of the plat plowed 5 inches deep (shallow plowing) was as high as that of any of the others. So far as the preparation of a seed bed is concerned, however, it was found that in most cases the shallow plowing was less desirable because the stubble was not turned under as well as by the deeper plowing. Because of this the surface of the shallow-plowed plat usually contained much trash,

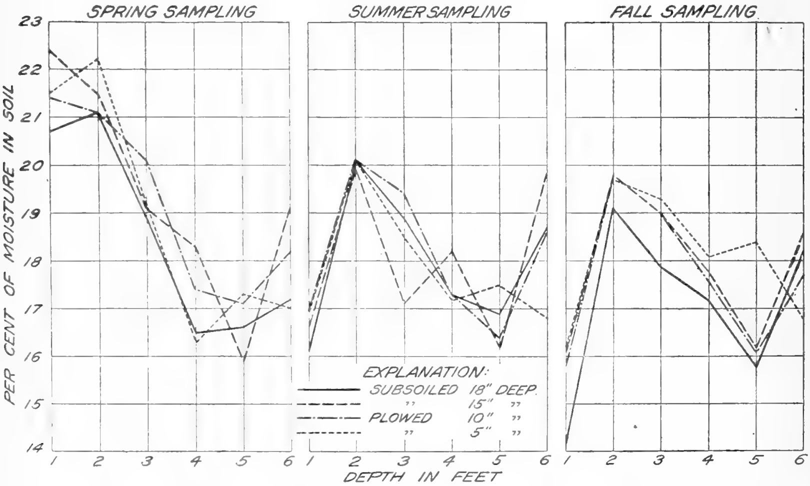

FIG. 6.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the fall depth-of-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

which interfered somewhat with the operation of the drill when the plat was seeded.

YIELD OF GRAIN.

The annual and average yields of the plats in these tests are presented in Table V and are shown graphically in figure 8.

TABLE V.—*Annual and average yields of winter wheat on plats used in the depth-of-plowing tests at the Nephi substation, 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Subsoiled 18 inches deep	14	28	18	4	16.0
Subsoiled 15 inches deep	13	29	19	6	16.7
Plowed 10 inches deep	13	29	21	7	17.5
Plowed 5 inches deep	12	27	20	10	17.2

The yields obtained in this test, as shown in Table V, agree with the moisture content of the plats, as previously discussed. The highest average yield was obtained from the plats plowed 10 inches deep, and the lowest average yield was obtained from the plats subsoiled 18 inches deep, while the plats plowed 5 inches deep gave better yields than those subsoiled 15 inches deep. The widest difference in the yields, however, is not significant. The point most strongly emphasized by the results is that there was no material difference in the yields obtained from plats plowed at depths varying from 5 to 18 inches.

RELATIVE COST OF PLOWING AND SUBSOILING.

Since there was no material difference in the moisture content or in the yields of the plats included in the depth-of-plowing tests, it is

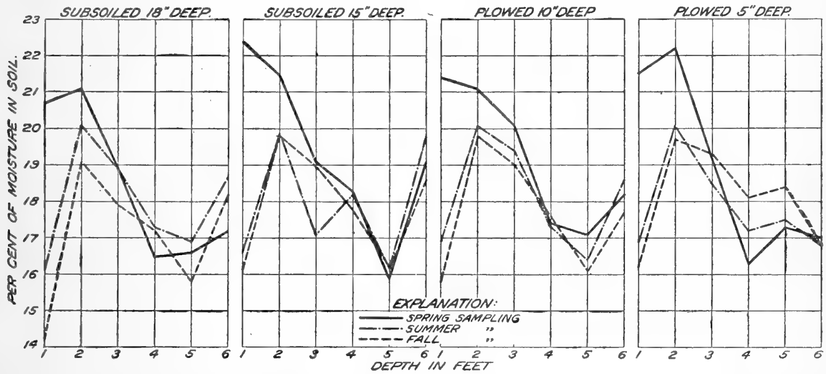

FIG. 7.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the fall depth-of-plowing tests at the Nephi substation, 1909 to 1913, inclusive.

well to consider the cost of crop production on the plats to determine, if possible, the comparative value of each operation. The subsoiled plats were first plowed and then subsoiled, the subsoiler following in the plow furrow. The draft of the subsoiler was as great as that of the plow; hence, the subsoiling entailed twice the expense of plowing and did not increase the yield of the plat. For this reason there was nothing in favor of and much against subsoiling as tested at Nephi.

There was so little difference between the yields of the two plowed plats that it is difficult to see any advantage in favor of deep plowing over shallow plowing. In fact, when considered from the standpoint of net returns, there was no advantage for deep plowing, because of the greater expense incurred. The most evident point in favor of deep plowing seems to be, as previously noted, that it covers the stubble better and this obviates some trouble at seeding time. Had some plats been plowed at different depths between 5 and 10 inches and some others plowed at these same depths in the spring as well as in the fall, it is possible that some more significant data

would have been obtained. With the data available, however, the question seems to be not so much how deep to plow as how well to plow.

DEPTH OF FALL AND SPRING PLOWING.

As already stated, there is always need in the spring of replowing or double disking land that has been plowed the previous fall. Because of this condition, an experiment was commenced in 1911 to determine whether it is best to plow deep in the fall and then shallow in the spring, or vice versa. In this test, plats 24C and 25C have been used alternately with plats 25A and 26A. One plat was plowed

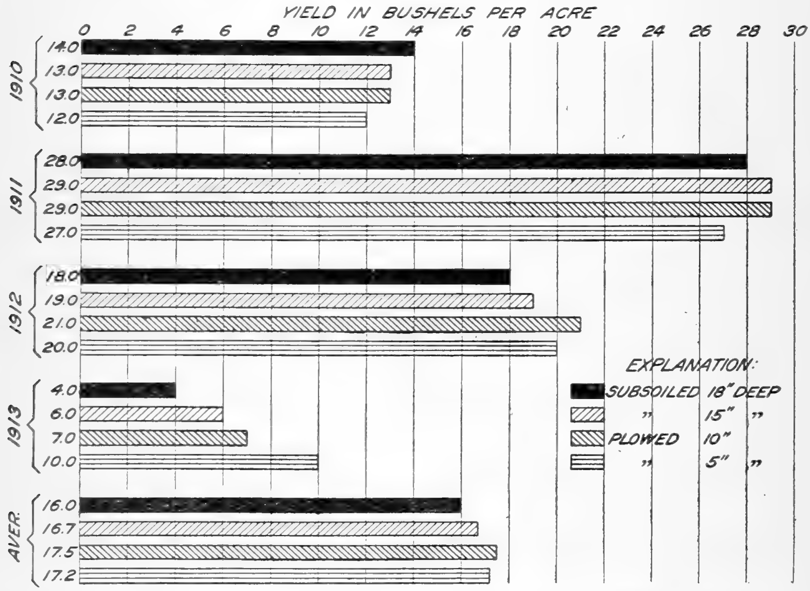

FIG. 8.—Diagram comparing the annual and average yields obtained in the fall depth-of-plowing tests at the Nephi substation, 1910 to 1913, inclusive.

only 3 inches deep in the fall, while the other was plowed 8 inches deep at the same time. The following spring the plat which was fall plowed 3 inches deep was replowed 8 inches deep, while the other plat was replowed only 3 inches deep. These plats were compared with an adjacent plat treated according to general practice in the region.

The soil-moisture determinations made in 1912 show no difference between the two methods. The yields of 1913, however, slightly favor the plat plowed 8 inches deep in the fall and 3 inches deep in the spring, but the difference is not significant. The test must be continued for several years before the results will be of value.

CULTIVATION OF FALLOW.

The purpose of the experiments in cultivating fallow land has been to determine the value of cultivation as compared with no cultivation. Very little has been done to determine the relative value of such factors as depth, method, and frequency of cultivation, etc., further than to observe and to note differences whenever they were apparent. These factors are so variable, however, that the notes made do not suggest any established principles.

Cultivation of Fall-Plowed Fallow.

Since 1908 two pairs of plats, alternately cropped and fallowed, have been used at Nephi in an endeavor to determine the value of cultivation as compared with no cultivation of fall-plowed fallow. Two adjacent plats were plowed uniformly in the fall of each year, and both were allowed to lie in a rough condition through the following winter. During the next spring and summer one of these plats received normal cultivation, while the other was not cultivated. Both were seeded uniformly in the fall and the further treatment of the plats was identical. These two plats alternated with two other plats which received the same treatment.

The cultivated fallow plat was replowed or double disked in the spring after fall plowing, to destroy weeds and volunteer grain. It was then harrowed, and during the succeeding summer it was harrowed and weeded as often as necessary. At least three harrowings were given the plat—one in the spring, one in the summer, and another just prior to the time of seeding; and the plat was weeded once or twice. On the other plat, weeds and volunteer grain were allowed to grow, but all growth was clipped before it matured, in order to minimize subsequent weed trouble.

MOISTURE CONTENT OF FALLOW.

Soil samples were taken from the fallow plats at the beginning, in the middle, and at the end of the season. Six-foot borings were made and the moisture content of each foot section was determined in the usual manner. The data obtained from these determinations are presented in Table VI, which shows the annual and average percentages of moisture in each foot and the average percentages in the 6 feet in the spring, in the summer, and in the fall for both the cultivated and the uncultivated fallow for the four years 1909 to 1912, inclusive.

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TABLE VI.—*Annual and average percentages of moisture in each of the first 6 feet of soil on cultivated and uncultivated fallow at the Nephi substation, samples taken in spring, summer, and fall, for the years 1909 to 1912, inclusive.*

FALLOW CULTIVATED NORMALLY.

Depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Average.		
	Apr. 21.	June 15.	Sept. 18.	Apr. 15.	June 24.	Sept. 6.	Apr. 18.	June 12.	Sept. 21.	Apr. 25.	June 26.	Sept. 16.	Spring.	Summer.	Fall.
1 foot	19.22	16.35	17.15	14.50	16.05	13.53	18.82	17.39	12.52	21.67	14.07	14.47	18.55	15.97	14.42
2 feet	19.60	19.65	16.55	18.20	18.80	19.35	19.69	19.53	17.74	22.06	19.87	18.88	19.89	19.46	18.13
3 feet	19.50	19.50	18.85	18.95	17.85	18.03	18.65	19.63	17.72	20.05	18.47	17.85	19.29	18.86	18.11
4 feet	19.40	18.90	18.70	19.33	19.63	18.68	14.95	18.80	16.56	13.32	14.20	14.10	16.75	17.88	17.01
5 feet	18.20	18.00	18.05	19.05	18.33	19.15	13.41	20.80	15.31	10.44	10.95	12.53	15.28	17.02	16.26
6 feet	20.00	20.30	19.35	19.30	18.80	18.45	17.44	17.60	17.89	15.85	13.92	13.54	18.15	17.66	17.31
Average	19.32	18.78	18.11	18.22	18.24	17.86	17.16	18.96	16.29	17.23	15.25	15.23	17.98	17.81	16.87

FALLOW NOT CULTIVATED.

Depth of sampling.	Apr. 21, 1909	June 15, 1909	Sept. 18, 1909	Apr. 15, 1910	June 24, 1910	Sept. 6, 1910	Apr. 18, 1911	June 12, 1911	Sept. 21, 1911	Apr. 25, 1912	June 26, 1912	Sept. 16, 1912	Spring	Summer	Fall
1 foot	18.60	12.65	12.30	12.85	10.45	8.05	20.00	12.83	9.61	20.47	10.68	7.95	17.98	11.65	9.32
2 feet	19.30	15.80	13.20	17.37	14.05	12.23	20.16	14.99	12.98	20.75	12.36	11.46	19.30	14.30	12.47
3 feet	20.45	16.55	14.15	19.10	13.28	11.78	17.88	17.08	12.28	17.21	12.91	11.18	18.66	14.96	12.35
4 feet	19.35	17.55	15.25	18.93	13.80	10.38	12.03	14.89	11.61	10.83	11.35	10.74	15.29	14.40	12.00
5 feet	19.05	18.15	16.15	19.35	16.18	13.45	11.10	13.94	11.20	11.27	14.47	11.86	15.19	15.69	13.17
6 feet	20.57	20.42	18.95	19.10	16.63	15.33	13.10	18.11	12.06	14.17	15.76	12.27	16.74	17.73	14.65
Average	19.55	16.85	15.00	17.79	14.06	11.87	15.71	15.31	11.62	15.78	12.92	10.91	17.20	14.79	12.34

Table VI shows that the moisture content of the plats was practically uniform in the spring, but that the differences increased as the season advanced. The moisture in the cultivated plat remained practically the same throughout the season, while that of the uncultivated plat rapidly decreased until by fall it was reduced to a comparatively low point. The first 4 feet seemed to lose more moisture than the fifth and sixth. These data are shown graphically in figures 9, 10, and 11. The fact that the moisture content of the second, third, and fourth feet of the uncultivated plat was reduced practically as much as on any of the cropped plats sampled suggests that a great deal of the moisture loss from the uncultivated plat was due to the growth of weeds and volunteer grain.

YIELD OF GRAIN.

The difference in the soil-moisture content of the plats, as shown in Table VI and figures 9, 10, and 11, is reflected in the yields obtained. These are reported in Table VII and are compared graphically in figure 12. It will be noticed that there is a difference of 4 bushels per acre in the average yield for the four years in favor of the cultivated plats. This difference is more than enough to pay for the cultivation of the fallow.

TABLE VII.—*Annual and average yields of winter wheat on cultivated and uncultivated fallow at the Nephi substation, for the years 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Fallow cultivated	13	29	21	5	17
Fallow not cultivated	14	18	15	5	13

CULTIVATION OF SPRING-PLOWED FALLOW.

In the spring of 1912 tests similar to the ones last discussed were begun on spring-plowed fallow. Both plats produced winter wheat

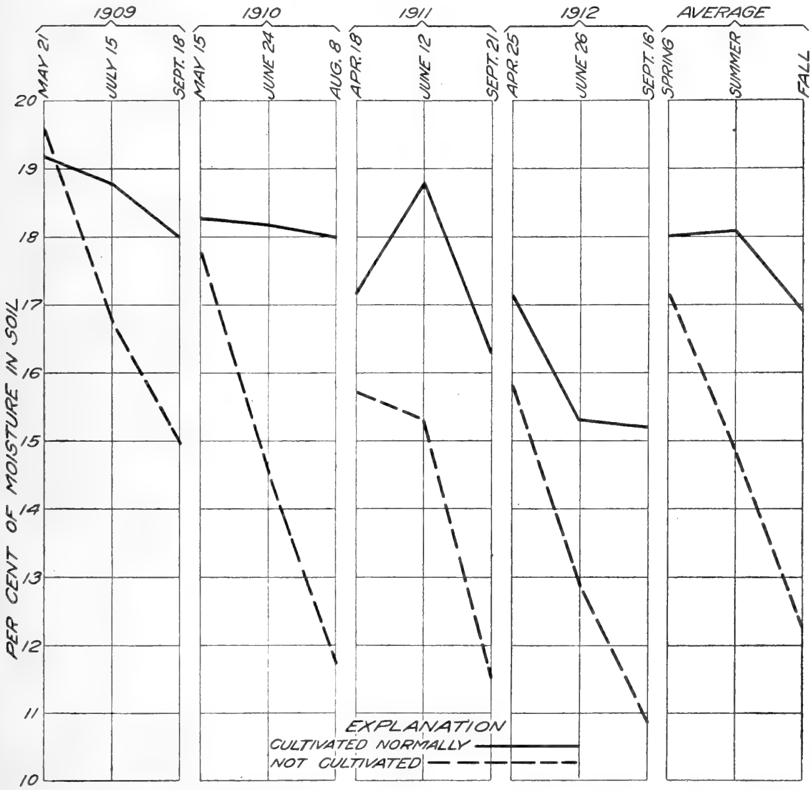

FIG. 9.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

in 1911 and were left in stubble during the winter. They were plowed uniformly as soon as possible the next spring. One was then cultivated normally during the summer of 1912, while the other was not cultivated. There were practically no weeds or volunteer grain on

either plat, but whatever growth appeared on the cultivated plat was destroyed, while on the uncultivated plat it was allowed to remain but not to mature. Both plats were seeded uniformly in the fall of 1912 and they were treated alike during 1913. Two alternate plats were added to the test in 1912.

Soil samples were taken from the fallow plats, and moisture determinations were made. These showed no appreciable difference in the moisture content of the plats in either the individual foot sections or the 6-foot averages. There was a uniform decline in the moisture content of the plats from spring to seeding time in the fall. The

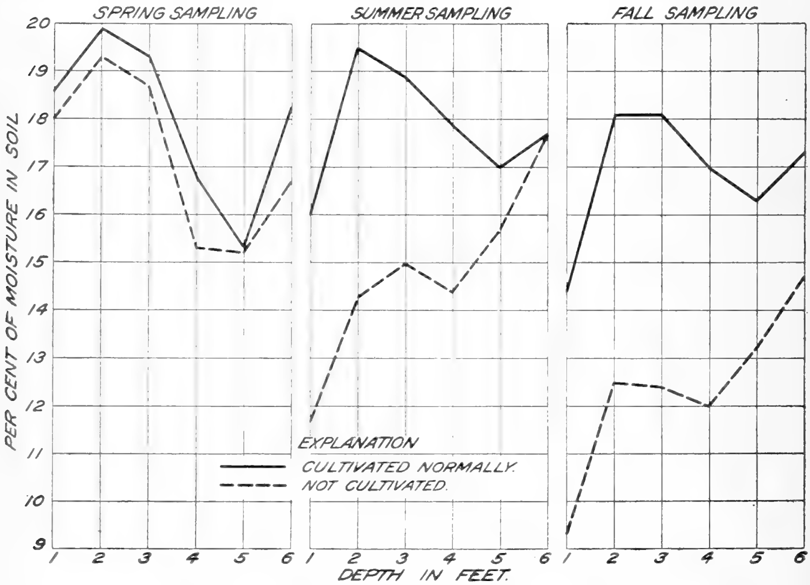

FIG. 10.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

yield of the plats in 1913, 11.9 and 9.5 bushels per acre, slightly favored the noncultivated plat, but there was so much winterkilling on both that the yields are not significant.

The value of these tests was increased in 1912 by the addition of nine other plats, treated as follows: Two plats, light cultivation; two plats, medium cultivation; two plats, heavy cultivation; and three plats, no cultivation.

These nine plats will be kept free from all vegetative growth. The noncultivated plats will be weeded with the least possible disturbance of the soil, thus affording an opportunity to study the value of cultivation methods for moisture conservation alone and not in connection with weed eradication.

SEEDING WINTER CEREALS.

Four important factors related to the seeding of winter cereals, namely, the time, depth, method, and rate of seeding, have been rather extensively considered in the experimental work of the Nephi substation since its beginning. All these factors are interrelated and are so regarded in ordinary farm practice, but at Nephi each has been

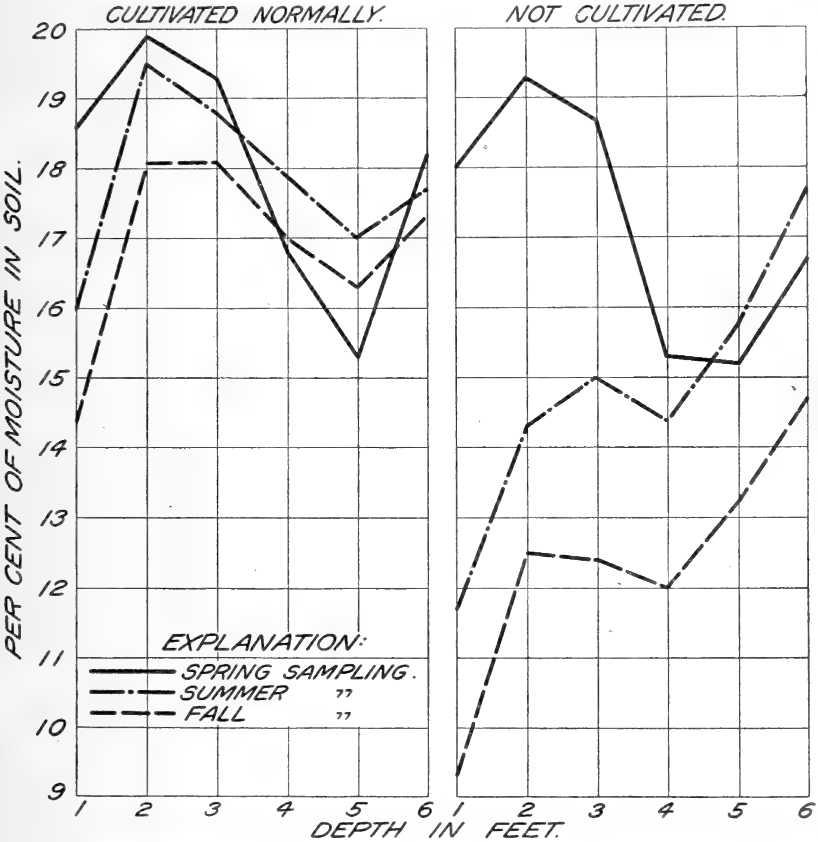

FIG. 11.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

considered apart from the others arbitrarily, and the results are so presented herein.

TIME OF SEEDING WINTER CEREALS.

WHEAT.

The experiments dealing with the time of seeding winter wheat have been in progress since 1903. During that time winter wheat has been sown each year at a uniform rate of 3 pecks to the acre on

each of the following dates: August 15, September 1, September 15, October 1, October 15, and November 1. In the years from 1904 to 1907, inclusive, the variety used was the Odessa (C. I. No. 3274). This variety was replaced by the Koffoid (C. I. No. 2997) in 1908 and 1909. From 1910 to 1913 both the Koffoid and the Turkey (C. I. No. 2998) have been used. Table VIII shows the average yields for the 6 years from 1904 to 1909, inclusive; the annual and average yields for both varieties for the 4 years from 1910 to 1913, inclusive; and the average yields for the entire 10-year period for

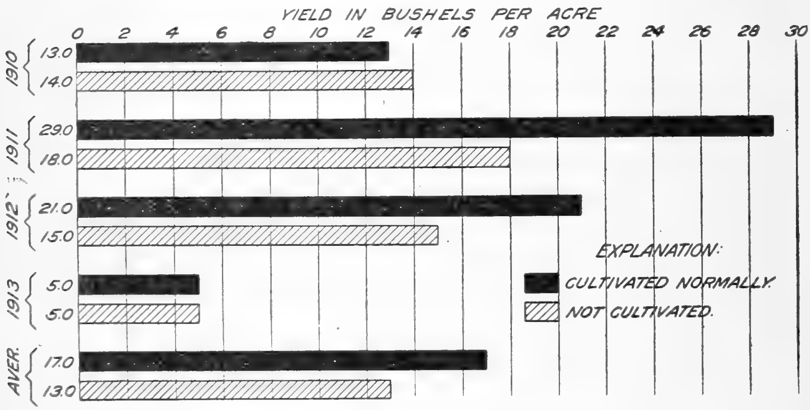

FIG. 12.—Diagram comparing the annual and average yields obtained in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1910 to 1913, inclusive.

each of the six dates upon which the grain was sown. The average yields for the 10-year period are presented graphically in figure 13.

TABLE VIII.—*Annual and average yields of two varieties of winter wheat for the years 1910 to 1913, showing also the average yields of one variety for the years 1904 to 1909, and of all varieties for the years 1904 to 1913, inclusive, in date-of-seeding tests at the Nephi substation.*

Date seeded.	Yield per acre of grain (bushels).											
	Annual yields.								Average yields.			
	1910		1911		1912		1913		1910–1913		1904–1909,[1] one variety.	1904–1913, all varieties.
	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.		
Aug. 15	15.60	27.30	21.70	23.50	13.50	13.40	Failure.	1.70	12.70	16.48	17.95	16.61
Sept. 1	32.20	36.80	17.80	28.60	6.30	5.30	0.67	6.83	14.24	19.38	20.32	18.92
Sept. 15	12.20	20.80	33.80	36.50	9.40	7.70	2.67	10.83	14.52	18.96	15.99	16.29
Oct. 1	9.50	13.50	29.90	26.40	17.80	15.90	3.00	10.67	15.05	16.62	22.00	19.53
Oct. 15	11.70	16.00	22.50	6.00	15.70	7.30	1.17	8.83	12.77	9.53	22.68	18.07
Nov. 1	14.20	17.80	9.20	10.00	4.20	7.30	(2)	(2)	9.20	11.70	20.46	17.12

[1] The average yields for the six years from 1904 to 1909 presented here were taken from Circular 61, Bureau of Plant Industry, U. S. Department of Agriculture, in which they were presented in connection with the annual yields for the same period.

[2] Not sown, because of stormy weather.

The results presented in Table VIII show no correlation between time of seeding and yield. Early seeding has given the best results in some years, while in others the best yields have come from late seeding, especially those in October. It will be observed, however, that as a rule the best yields have come from seeding between September 1 and October 15.

SOIL MOISTURE AT SEEDING TIME.

Beginning in the fall of 1908, the plats used in the time-of-seeding test were sampled to a depth of 6 feet just prior to the seeding of the plats. In the later years, when two varieties were sown, composite samples of both plats were taken. The percentages of moisture in

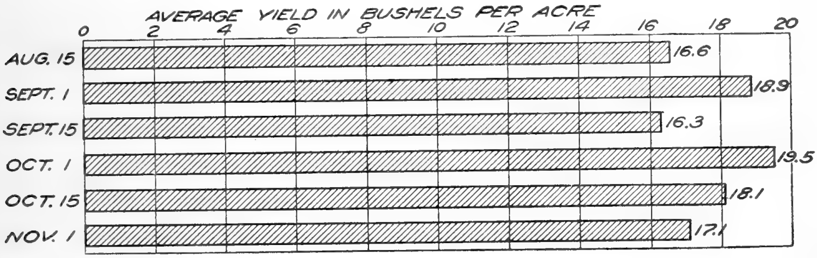

FIG. 13.—Diagram comparing the 10-year average yields of winter wheat obtained in the time-of-seeding tests at the Nephi substation, 1904 to 1913, inclusive.

each foot of soil at seeding time as shown by these samples are given in Table IX.

TABLE IX.—*Annual and average percentages of moisture in each of the first 6 feet of soil at different dates of seeding at the Nephi substation, for the years 1908 to 1912, inclusive.*

Date of seeding.	Depth of sampling.	1908 [1]	1909	1910	1911	1912	Average.
Aug. 15	1	16.40	14.60	12.85	12.67	13.65	14.03
	2	17.30	19.05	17.44	15.55	17.75	17.42
	3	14.12	17.10	16.12	10.87	14.48	14.54
	4	12.45	18.30	17.33	10.84	12.40	14.26
	5	12.95	20.60	18.25	12.24	9.88	14.78
	6	12.37	18.15	17.20	14.48	11.60	14.76
Average		14.26	17.96	16.53	12.78	13.29	14.96
Sept. 1	1	15.95	17.30	14.73	11.60	15.65	15.05
	2	18.10	18.30	17.33	15.04	18.83	17.52
	3	15.35	17.75	16.28	11.80	15.87	15.41
	4	10.70	19.45	17.05	10.75	12.03	14.00
	5	9.75	17.75	16.50	8.01	10.60	12.52
	6	10.82	18.30	19.15	9.08	13.12	14.09
Average		13.44	18.14	16.84	11.05	14.35	14.76
Sept. 15	1	16.32	17.45	12.10	9.97	11.91	13.55
	2	16.70	18.75	17.38	12.53	16.69	16.41
	3	14.92	17.00	16.53	11.20	15.24	14.98
	4	10.22	17.55	17.45	12.44	13.09	14.15
	5	10.57	16.85	16.22	11.93	9.23	12.96
	6	11.45	17.40	17.65	11.00	10.61	13.62
Average		13.36	17.50	16.22	11.51	12.80	14.28

[1] One plat only. In each of the other years the figures given are the average of two plats.

TABLE IX.—*Annual and average percentages of moisture in each of the first 6 feet of soil at different dates of seeding at the Nephi substation, for the years 1908 to 1912, inclusive*—Continued.

Date of seeding.	Depth of sampling.	1908 [1]	1909	1910	1911	1912	Average.
Oct. 1	1	20.00	15.60	12.88	13.47	12.55	14.90
	2	19.40	18.90	16.43	16.07	17.00	17.56
	3	15.55	16.00	16.58	14.98	14.49	15.52
	4	11.27	17.90	16.78	15.24	13.17	14.87
	5	10.77	16.70	18.38	14.34	13.57	14.75
	6	12.72	17.05	16.33	14.23	13.37	14.74
Average		14.95	17.02	16.23	14.72	14.03	15.39
Oct. 15	1	16.90	15.35	14.61	12.29	17.87	15.40
	2	18.60	17.75	16.80	14.98	18.59	17.34
	3	15.35	16.55	16.65	14.63	17.40	16.12
	4	14.10	16.05	16.33	13.57	15.92	15.19
	5	11.08	16.65	16.28	11.95	13.75	13.94
	6	10.92	17.75	18.00	13.14	15.45	15.05
Average		14.49	16.68	16.44	13.44	16.50	15,51
Nov. 1	1	18.55	13.95	17.85	14.68	(2)	16.26
	2	20.52	17.35	18.78	18.02		18.67
	3	19.72	16.20	18.30	14.60		17.21
	4	13.90	13.95	17.63	11.25		14.18
	5	11.15	14.15	17.05	8.97		12.83
	6	10.37	14.50	16.55	15.49		14.23
Average		15.70	15.02	17.69	13.84		15.56

[1] One plat only. In each of the other years the figures given are the average of two plats.
[2] Stormy weather prevented the sampling and seeding of these plats.

It will be noticed in Table IX that there was no great difference in the average moisture content of the plats. The surface foot, usually very dry in the first few inches, varied in moisture content to some extent, owing partly to rainfall, but even in this foot the variation is within the limits of experimental error. Moisture in the first foot of soil is of chief importance at seeding time, because it is here that the plant starts life, and for this reason some relation between the moisture content of the first foot of soil at seeding time and the yield of the crop might be expected. This relation failed to appear, however, in any one year. That it was not apparent in an average for the four years from 1909 to 1912 is shown in figure 14, in which the average moisture content of the first foot of soil on the six different dates of seeding, and the average yields of two varieties of winter wheat seeded on those dates are graphically presented.

Figure 14 shows an apparent relationship between the moisture content of the first foot of soil and the yields of the plats seeded on the two earlier dates, but for later dates the curves run almost parallel to each other. A discussion of the physical factors influencing the time of seeding will aid in explaining this condition.

FACTORS INFLUENCING THE TIME OF SEEDING.

On the dry lands of the Great Basin the best time for seeding winter wheat is greatly limited by climatic conditions. The long, dry summers exhaust the moisture of the fallow soil nearly to the depth to which the land is plowed, leaving the surface soil almost

dusty to a depth of 4 to 8 inches. This condition, combined with continued lack of rainfall, often prevents the sowing of wheat until very late in the fall, sometimes until farmers are compelled to sow in order to have the seed in the ground before snow falls. It is impracticable to sow seed in the dry soil, because it would not germinate until rain fell, and then, if the storms brought insufficient moisture for continued growth, the plant very likely would die after sprouting. This makes early seeding in dry soil precarious. Farmers, realizing this fact, seldom seed "in the dust," although good yields have sometimes been obtained from such seeding when it is followed by sufficient moisture for germination and continued growth.

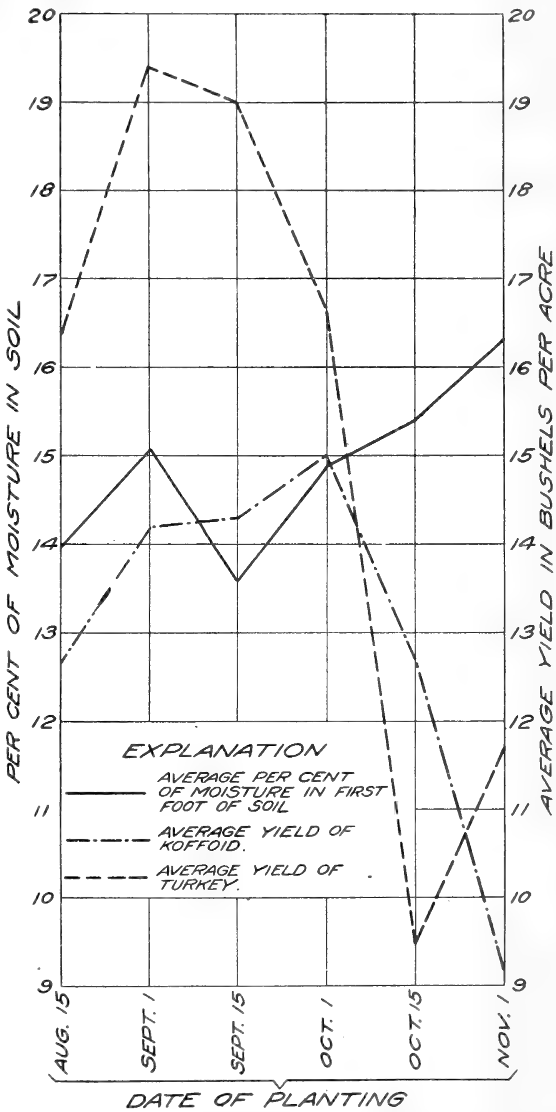

FIG. 14.—Graph showing the average percentage of moisture in the first foot of soil at seeding time in the fall and the average yields of two varieties of winter wheat used in the time-of-seeding tests at the Nephi substation, 1909 to 1913, inclusive.

It is almost impossible to place the seed below the dry soil, and, if it were possible, it is not practicable, because small seeds placed so deep often have difficulty in getting their first leaves to the surface. These facts explain why farmers generally wait for rain to wet the surface soil before they sow their wheat. In order to obtain the highest yields from winter wheat in the Great Basin, however, it is essential that the plants make at least a fair growth before winter begins. To get the desired growth, the seed should be sown

not later than October 1. When seeding is delayed until very late in the fall there is great danger of injury to the young plants if germination occurs, from what may be termed "fall killing." They are in a very critical condition when freezing weather arrives. An open winter following this injury results in almost total failure of the crop, regardless of the tillage methods used in preparing the land and of the amount of moisture stored in it.

As practical examples of the points brought out in the preceding discussion, the past four seasons, 1909–10 to 1912–13, are worthy of consideration. The seedings on August 15 and September 1, 1909, were made when, owing to recent rains, there was plenty of moisture in the first foot to cause good growth. The yields of these plats in 1910 were high in comparison with those of the plats sown later, when the weather was dry and cold. The seedings on September 15, 1910, were made under conditions similar to those in August, 1909. The yields on these plats were higher than those seeded "in the dust" in August and those sown late in October. In the fall of 1911 and again in 1912 the weather was dry until early October, after which time there was plenty of moisture, but the weather was cold. As a result of these conditions the yields of both early-sown and late-sown crops were low. Figure 15 shows the relation of precipitation to yield in this instance. The blackened portions of the figure illustrate the daily precipitation from August 1 to November 30, inclusive, and the curves represent the yields in bushels per acre of the two varieties of wheat seeded on different dates during these months.

It will be seen that early seeding if done in wet weather gave high yields, while it gave low yields, and sometimes almost failures, when done in dry weather. It is also shown that late seeding, even when there was plenty of moisture, often resulted in serious loss because of injury to the tender plants by freezing. There seems to have been some difference in the effect of these climatic conditions on the two varieties. This may have been due to a difference in the time of germination between the hard (Turkey) variety and the soft (Koffoid) variety. The writer is of the opinion that this difference in germination is largely responsible for the differences in yield. The soft wheat seems to germinate more rapidly than the hard wheat, and for this reason it is more advanced on a given date than the latter variety. This may not always be advantageous to it, as it may be in a tender stage of growth when drought or cold weather strikes it, and thus it may be injured more than the ungerminated seed of the hard variety. On the other hand, the soft wheat may be sufficiently far advanced to protect it from injury, while the slower germinating Turkey wheat may be still in a tender stage of growth.

The climatic and soil conditions under which these results were

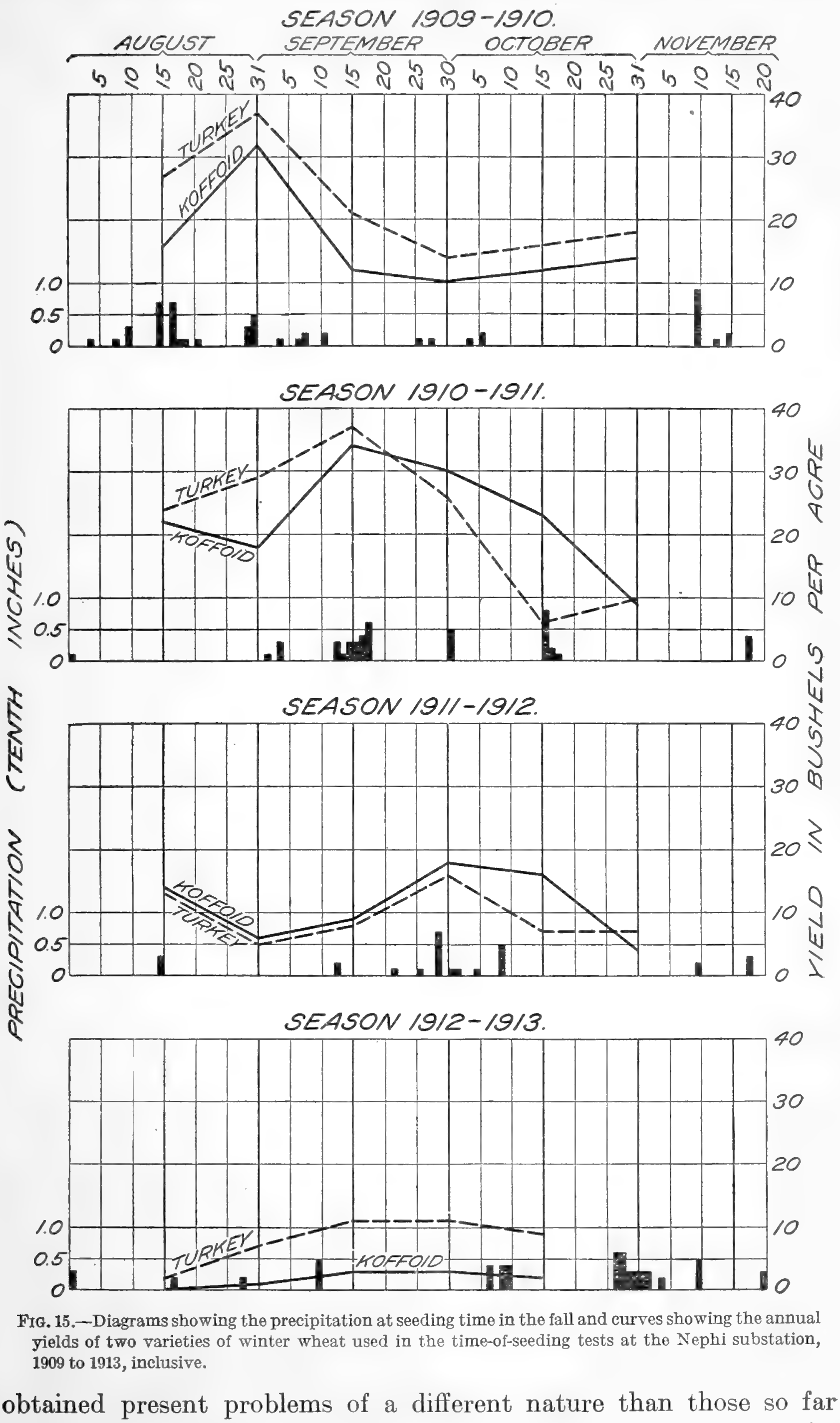

FIG. 15.—Diagrams showing the precipitation at seeding time in the fall and curves showing the annual yields of two varieties of winter wheat used in the time-of-seeding tests at the Nephi substation, 1909 to 1913, inclusive.

obtained present problems of a different nature than those so far

studied. Early seeding, not later than October 1, seems desirable, but as this is not always practicable, owing to a dry seed bed, the chief problem seems to be a mechanical one involving some improvement of the machinery now used in seeding the grain. The improvement believed to be necessary comprises a means for opening a furrow through the dry surface soil, sowing the seed in moist earth at the bottom of the furrow, and leaving the furrow partly open so that the plants will not have to force their way through several inches of dry soil. It is believed that seed could be sown with good results in dry weather by this method, as the seed would germinate rapidly and a good stand of grain would be established before winter, thus greatly increasing the possibilities of a good crop.

BARLEY, OATS, AND EMMER.

In the fall of 1911 date-of-seeding tests with winter barley, winter oats, and winter emmer were begun. Four dates were used for each grain, namely, September 1, September 15, October 1, and October 15. All grains were sown at the rate of 6 pecks per acre on the "oats" side of the drill. As has already been explained in connection with the discussion of the time of seeding winter wheat, there was much winterkilling in the seasons of 1911–12 and 1912–13, and, consequently, the results obtained from these experiments with barley, oats, and emmer are of little value. The tests are being continued, however.

Depth of Seeding Winter Cereals.

Depth-of-seeding tests with winter wheat have been in progress since the fall of 1908, while similar tests with winter barley, winter oats, and winter emmer were begun in 1911. In all the tests, seed has been sown at three different depths, 1.5, 3, and 6 inches, the drill being set in the first, second, or third notch, according to the depth desired. In all respects other than depth of seeding, the plats in each test were treated uniformly.

Each fall the plats were seeded at what was considered the best time. Sometimes, as in 1909 and 1910, it was possible to sow the seed early enough to obtain a fair growth before winter and, as a result, good yields were obtained. On the other hand, as in 1908, 1911, and 1912, seeding was not possible until very late in the season, resulting in poor yields, for reasons already explained.

The yields of winter barley, oats, and emmer were so small in 1912 and 1913, because of late seeding and subsequent freezing, that they are not dependable and need not be presented here. The yields of winter wheat in 1913 also were very small, but as they are important in connection with the results of the preceding four years, the yields for the five years are presented in Table X.

TABLE X.—*Annual and average yields of winter wheat sown at different depths at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Depth planted.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
About 1.5 inches (drill in first notch)	4.30	20.20	27.70	16.30	3.20	14.34
About 3 inches (drill in second notch)	[2] 4.07	16.60	28.50	16.30	2	13.49
About 6 inches (drill in third notch)	2.10	15	27.20	19.10	2	13.08

[1] The Koffoid variety (C. I. No. 2997) was used in 1909, while Turkey (C. I. No. 2998) was used from 1910 to 1913, inclusive.
[2] Average yield of seven check plats.

The results of five years as recorded in Table X show very little difference in the average yield of winter wheat seeded at different depths. The yields of 1910, a good season, favored shallow seeding. Those of 1911, a better season, showed a slight advantage in favor of a medium depth of seeding. In fact, it seems that depth of seeding is less important than time of seeding, which, as has been shown, is governed at present by soil and climatic conditions.

METHOD OF SEEDING WINTER WHEAT.

Tests designed to determine the relative value of broadcasting, ordinary drilling, and cross drilling have been carried on at Nephi for several years. After what has been said concerning the soil and climatic conditions which usually obtain at seeding time in the fall, it is easy to see why broadcasting has been not nearly so successful as drilling. The broadcast plats have been practically failures each season that method of seeding has been tested, while the drilled plats yielded from 20 to 25 bushels per acre.

On the cross-drilled plats the drill was first drawn lengthwise and then crosswise of the plat. On one plat the usual rate of seeding, 3 pecks per acre, was used, while on the other twice the usual rate, or 6 pecks per acre, was used. In the one case the drill was set to sow at the rate of 1.5 pecks to the acre and in the other at the rate of 3 pecks, the cross drilling making the quantities sown double those just mentioned. Near these two plats there was always one seeded in the usual manner at 3 pecks per acre. This plat, being usually a check plat, was not always seeded at the same time as the others, however, and so its yields are not strictly comparable with those of the cross-drilled plats. All are presented, however, in Table XI, which gives the annual and average yields for the five years from 1909 to 1913, inclusive.

TABLE XI.—*Annual and average yields of winter wheat drilled in the ordinary manner and cross drilled at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Method and rate of drilling.	Yield per acre of grain (bushels).						
	1909	1910	1911	1912	1913	Average.	
						5 years.	4 years.
Ordinary drilling at 3 pecks per acre	[2] 4.07	16.60	22.30	16.30	5.17	12.89	15.09
Cross drilling, 1.5 pecks per acre each way	3.50	18.50	26.70	17.10	6.00	14.36	17.08
Cross drilling, 3 pecks per acre each way	....	17.80	28.80	17.60	5.34	....	17.39

[1] The Koffoid variety was used in 1909, while the Turkey was used from 1910 to 1913, inclusive.
[2] Average of seven check plats.

Table XI shows that the difference between the yields of the cross-drilled plats and those drilled in the ordinary manner, both seeded at the rate of 3 pecks per acre, is very small, almost insignificant when the comparative cost of seeding is considered. It is not known whether the difference in yield favoring the cross-drilled plats is caused by cross drilling or by a possible increase in the rate of seeding which may have occurred owing to the double seeding, i. e., the drill may have seeded more than 3 pecks when set to sow 1.5 pecks each way of the plat. It is believed that the increase in the rate of seeding is responsible for the higher yield of the plats seeded at 6 pecks per acre, since these results agree with those of the rate-of-seeding tests with winter wheat.

RATE OF SEEDING WINTER WHEAT.

Rate-of-seeding tests with winter wheat were conducted at Nephi for the three years from 1909 to 1911, inclusive, and they were repeated in 1913. There was no test of this kind in 1912. In each year six different rates of seeding were used, namely, 2, 2.5, 3, 4, 5, and 6 pecks per acre. All plats in the test were treated uniformly in every way except as to the rate of seeding. The annual and average yields in bushels per acre obtained are presented in Table XII.

TABLE XII.—*Annual and average yields of winter wheat in the rate-of-seeding test at the Nephi substation in 1909, 1910, 1911, and 1913.*[1]

Rate of seeding per acre.	Yield per acre of grain (bushels).					
	1909	1910	1911	1913	Average.	
					4 years.	3 years (1910, 1911, and 1913).
2 pecks	4.16	16.00	23.50	Failure.	10.92	13.17
2.5 pecks	....	15.30	28.50	Failure.	....	14.60
3 pecks (ordinary)	....	19.30	21.30	2.67	....	14.42
4 pecks	7.75	19.30	28.70	3.00	14.69	17.00
5 pecks	4.80	19.30	33.70	2.83	15.16	18.61
6 pecks	2.33	17.00	30.30	3.00	13.16	16.77

[1] The Koffoid variety was used in 1909, while the Turkey was used in 1910, 1911, and 1913.

The principal fact brought out by Table XII is that the higher rates of seeding have given the largest average yields. This is rather contrary to the belief of dry-land farmers in the Great Basin, who fear that heavier seeding than 3 pecks to the acre would be disastrous to the crop in extremely dry seasons. That this view is not well founded is shown by the fact that in 1910 and 1911, the two driest years at Nephi since 1898, the highest rates of seeding gave yields as high as, or much higher than, the lower rates. The results available indicate that a 4-peck or 5-peck rate is the most profitable.

It is likely that 3 pecks per acre would be sufficient if all seeds sown produced plants that matured, but it has been found at Nephi that the average winter survival among fall-sown cereals is about 65 per

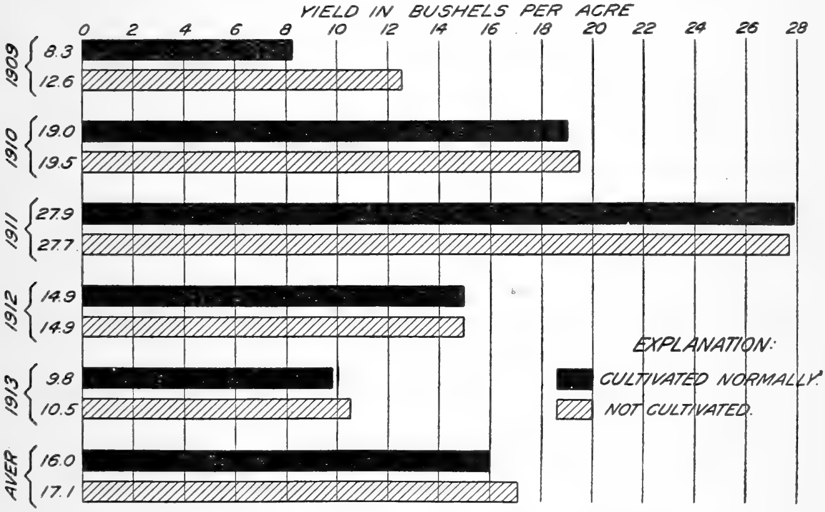

FIG. 16.—Diagram comparing the annual and average yields obtained in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

cent,[1] in which case only about 30 pounds of the seed produce plants that mature.

SPRING CULTIVATION OF WINTER WHEAT.

Two adjacent plats have been used each year since 1909 for testing the value of spring cultivation of winter wheat compared with no cultivation. These plats were treated uniformly in every other respect. Normal cultivation consists of harrowing the crop, usually with a spike-toothed harrow, as early in the spring as advisable, repeating this operation, if necessary, before the plants are in boot.

The chief value of spring cultivation, it was thought, would be found in its favorable influence upon the yield of the crop by breaking the crust which usually forms upon the surface of the ground during the winter and early spring. The destruction of this crust was

[1] Cardon, P. V. Cereal investigations at the Nephi substation. U. S. Dept. Agr. Bul. 30, p. 34, 1913.

expected to create a mulch which would prevent the evaporation of soil moisture and allow the plant greater freedom for growth. These factors constitute the basis of a great deal of argument in favor of the spring cultivation of winter wheat, a practice which is rather general in the Great Basin area. The results obtained are quite contrary to those which were expected.

YIELD OF GRAIN.

The annual and average yields of the plats for 1909 to 1913, inclusive, are given in Table XIII and are shown graphically in figure 16.

TABLE XIII.—*Annual and average yields of winter wheat obtained from cultivated and uncultivated plats at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Treatment.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
Cultivated	8.33	19.00	27.90	14.90	9.83	15.99
Not cultivated	12.66	19.50	27.70	14.90	10.50	17.05

[1] The Koffoid variety was used in 1909, while the Turkey was used in 1910 to 1913, inclusive.

It is of peculiar interest to note that in four of the five years there has been practically no difference in the yields obtained in this test. The yield of the noncultivated plat has been higher in three of the five years, while in 1911 the difference of 0.2 of a bushel per acre favored the cultivated plat. The yields of 1912 were identical. The difference in the average yield of 1.06 bushels in favor of the noncultivated plat is largely due to the greater yield of this plat in 1909.

EFFECT ON SOIL MOISTURE.

Soil samples were taken each year from each of the plats, usually at the beginning, in the middle, and at the end of the season. Six-foot samples were taken, and the moisture content of each foot section was determined in the manner previously described in this bulletin. The results are presented in Table XIV, which shows the annual and average percentage of moisture in each foot and for the entire 6 feet in the spring, in the summer, and in the fall.

Table XIV shows a marked uniformity in the moisture content of the two plats at the beginning, in the middle, and at the end of the season, the seasonal loss from both plats being about the same. The greatest difference was shown in 1909, when the cultivated plat with a thin stand of grain lost moisture less rapidly than the noncultivated plat, on which the stand was thicker. In all other years the stands were more nearly alike. Figures 17, 18, and 19 illustrate graphically the results shown in Table XIV. It is apparent that spring cultivation of winter wheat did not conserve any appreciable amount of

moisture in the 6 feet of soil sampled and that, so far as moisture conservation is concerned, no advantage was derived from the cultivation of the crop.

TABLE XIV.—*Annual and average percentages of moisture in each of the first 6 feet of soil on the plats used in the test of spring cultivation of winter wheat at the Nephi substation, samples taken in spring, summer, and fall, for the years 1909 to 1913, inclusive.*

Treatment and date of determination.	Depth of sampling.						Average.
	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.	
CULTIVATED.							
1909:							
June 26	12.60	16.25	18.02	18.50	19.25	17.63	17.04
August 12	12.75	15.20	15.45	18.95	16.70	12.82	15.31
1910:							
May 15	13.05	16.30	17.33	17.70	18.15	19.95	17.08
June 28	10.38	12.63	11.33	11.18	13.30	16.90	12.62
August 6	8.53	11.35	11.10	11.15	13.10	11.38	11.10
1911:							
April 26	18.28	21.90	20.46	18.90	17.80	15.65	18.83
September 20	9.12	12.13	11.95	11.48	14.72	13.42	12.14
1912:							
May 15	20.17	21.51	20.17	17.99	15.21	17.04	18.68
June 27	9.92	13.11	12.14	14.25	15.23	16.23	13.48
August 2	9.48	13.65	12.24	11.52	13.99	17.30	13.03
1913:							
May 17	20.50	22.22	21.38	18.32	15.98	15.54	18.99
June 20	10.83	15.77	15.63	15.73	15.54	15.06	14.76
September 6	10.67	13.49	12.24	11.43	13.58	12.49	12.32
Average in spring	18.00	20.48	19.84	18.23	16.79	17.05	18.40
Average in summer	10.93	14.44	14.28	14.92	15.83	16.46	14.72
Average in fall	10.11	13.16	12.60	12.91	14.42	13.48	12.78
NOT CULTIVATED.							
1909:							
June 26	13.15	16.15	17.20	17.28	16.85	15.22	15.97
August 12	10.65	12.90	12.20	10.15	11.05	13.45	11.73
1910:							
May 15	14.35	17.65	18.95	18.20	18.35	19.45	17.82
June 28	12.98	11.83	11.78	11.05	13.20	17.95	13.13
August 6	8.75	11.88	11.65	11.75	13.10	17.85	12.50
1911:							
April 26	18.79	22.69	21.79	19.60	19.07	17.78	19.95
September 20	8.91	13.39	13.08	12.51	15.13	13.25	12.71
1912:							
May 15	16.77	21.35	20.21	20.22	19.21	17.20	19.16
June 27	12.04	14.15	14.05	18.00	16.17	15.99	15.07
August 2	10.61	13.69	12.62	12.67	14.78	16.72	13.52
1913:							
May 17	18.88	20.59	20.20	19.10	17.12	19.04	19.16
June 20	10.73	15.80	17.21	15.91	16.23	16.95	15.47
September 6	11.30	12.88	12.29	12.05	15.18	13.83	12.92
Average in spring	17.20	20.57	20.29	19.28	18.44	18.37	19.02
Average in summer	12.23	14.48	15.06	15.56	15.61	16.53	14.91
Average in fall	10.04	12.95	12.37	11.83	13.85	15.02	12.68

EFFECT OF CULTIVATION ON THE PLANTS.

As already stated, the spring cultivation of winter wheat was expected to allow the plants greater freedom for development. It is not known to what extent this result obtained, but it is reasonable to believe that the surface of the soil was placed in better condition for plant development than where the crust was left unbroken and the plants compelled to push through it. It is, however, almost impossible to break the crust without injuring some plants. Whether this injury is offset by the benefit to others is difficult to determine,

though the yields of the past five years indicate that it is not. An effort was made in 1913 to determine the exact extent of the injury to the plants by harrowing with a spike-toothed harrow, the teeth of which were set almost perpendicularly. At this time there was a heavy crust on the ground, which the plants were penetrating with difficulty.

On May 21, when the plants were from 3 to 4 inches high, four areas were staked off on plat 22D, and the plants in each area were counted before the plat was harrowed. Each area was 3.3 feet square, thus containing $\frac{1}{4000}$ of an acre, so that the total area of the

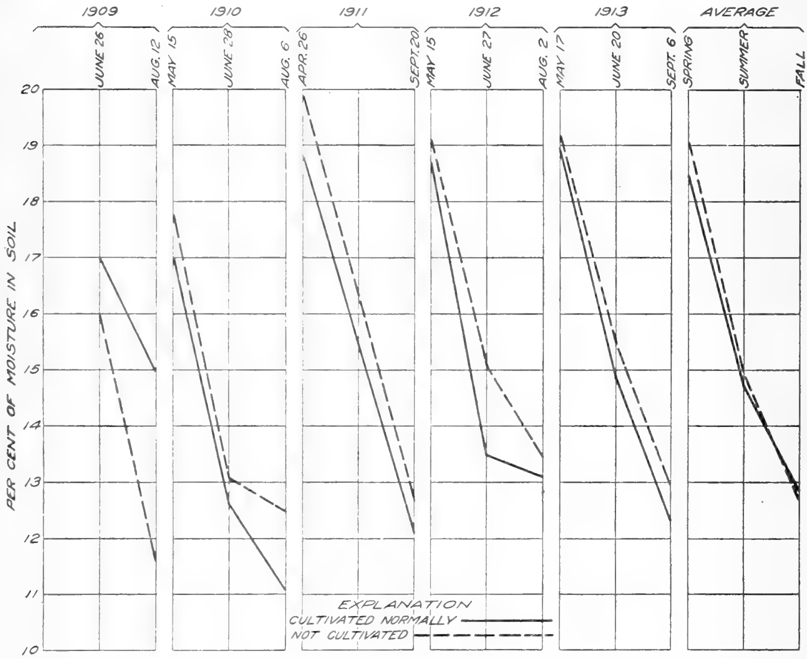

FIG. 17.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the crop season, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

four units equaled $\frac{1}{1000}$ of an acre. About one week after harrowing, the plants in each area were counted again and the loss due to harrowing was determined. On the basis of the figures obtained, the stand was 218,000 plants per acre before and 193,000 plants per acre after harrowing, a loss of 25,000 plants, or 11.54 per cent. This loss alone would allow the plants greater freedom for development, and it might be expected to increase the number of culms per plant.

To determine the effect of harrowing on the production of culms the total number per unit area was determined just before harvest and the average number of culms per plant calculated. The average

number on the cultivated plat was 4.17, while on the uncultivated plat it was 4.05. The particular areas which were counted on the uncultivated plat, however, showed a thinner stand than those on the cultivated plat, so that the number of culms per plant does not show entirely the difference in development. The number of plants per acre on the uncultivated plat, as indicated by the areas counted, was 165,000 with a total of 663,000 culms. On the cultivated plat, the stand was 193,000 plants to the acre, with 805,000 culms, which was over 21 per cent more than on the uncultivated plat. On only one of the four uncultivated areas counted was the stand as thick as on the cultivated areas. On this area the average number of culms

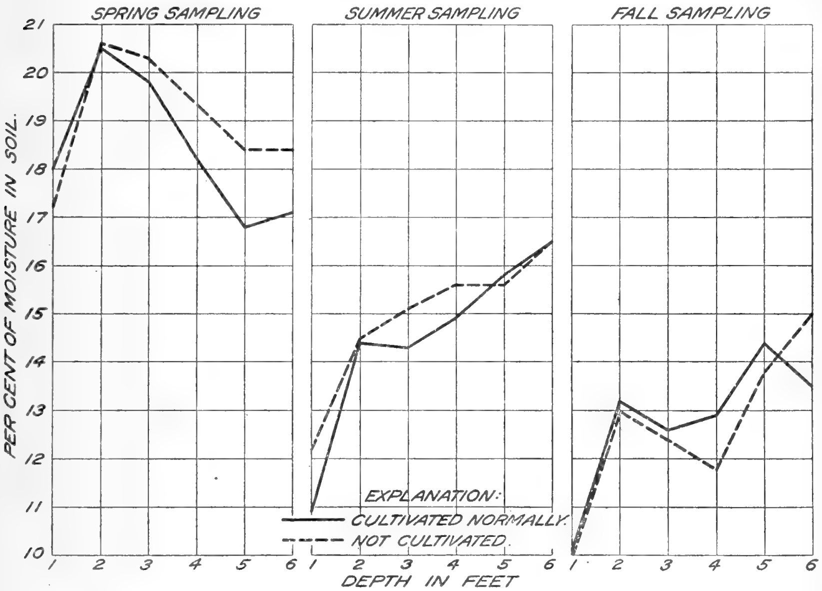

FIG. 18.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the crop season, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

per plant was 3.74. On a cultivated area, with practically the same stand, the number of culms per plant was 4.14, an increase of 11 per cent.

On the same areas on the uncultivated plats the average yield per unit area 3.3 feet square was 156 grams of straw and 103 grams of grain. On the areas in the cultivated plats the yields were 199 grams of straw and 114 grams of grain. These figures indicate that cultivation caused a marked increase (27.6 per cent) in yield of straw, but a much smaller increase (10.7 per cent) in yield of grain. The yields obtained on the unit areas are contradictory to those from the entire plats, as shown in Table XIV, which shows a decrease in yield on the cultivated plat of 6.4 per cent.

TIME OF HARVESTING WINTER WHEAT.

During the period from 1909 to 1912, inclusive, a test of the effect of the time of harvesting upon the yield and quality of winter wheat was conducted. The milling and chemical tests of the wheat were made by the division of chemistry of the Utah station, but the data are not available at this time. Only the data on yield will be presented here.

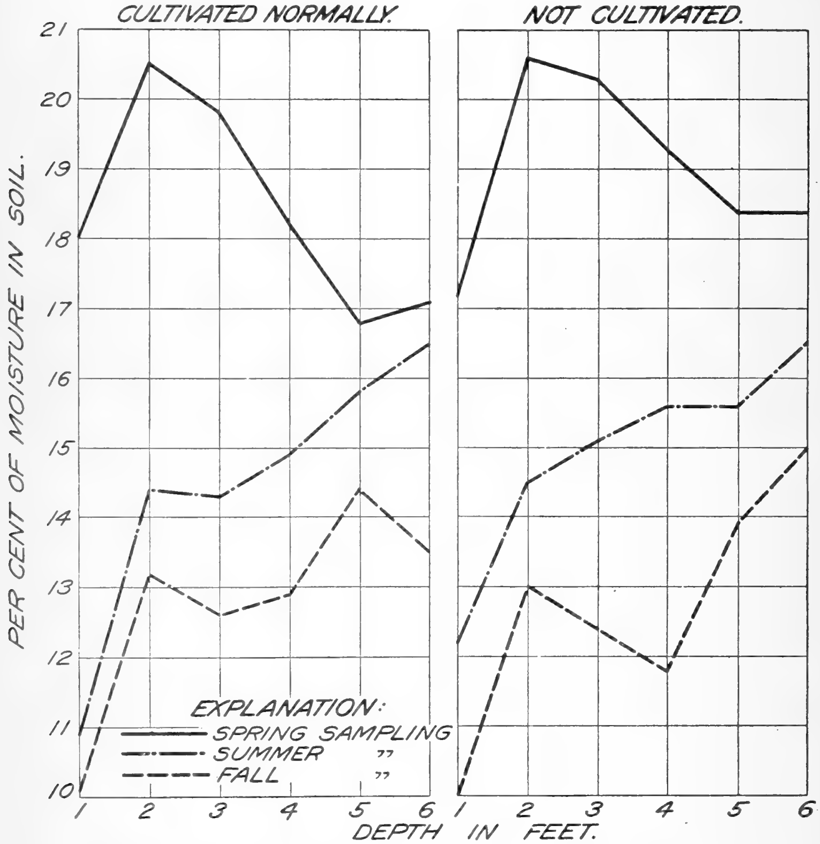

FIG. 19.—Graphs showing the average seasonal decline in the percentage of moisture in each of the upper 6 feet of soil, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

The four plats used in this test lay side by side and were treated uniformly up to and subsequent to the time of harvesting. One of these plats was harvested when the kernel was in the green-dough stage and one each week thereafter until all were harvested. In this way the grain was cut in four different stages of maturity, namely, green dough, hard dough, fully ripe, and overripe. The annual and average yields of the plats for the four years are given in Table XV.

TABLE XV.—*Annual and average yields of winter wheat harvested at four different stages of maturity at the Nephi substation, for the years 1909 to 1912, inclusive.*

Stage of maturity when harvested.	Yield per acre of grain (bushels).				
	1909	1910	1911	1912	Average.
Green dough	7.83	8.80	20.30	6.50	10.86
Hard dough	8.83	14.00	26.40	10.20	14.86
Fully ripe	6.33	13.80	24.60	11.50	14.06
Overripe	8.50	12.70	20.70	11.80	13.43

Table XV shows that with one exception the yield each year favored harvesting in the hard-dough stage, though the differences are not great. The earliest harvest gave the smallest yields, due probably to the shrinking of the grain. The small decrease in the average yield from hard dough to overripe was probably due to shattering at harvest time.

FREQUENCY OF CROPPING LAND TO WINTER WHEAT.

One of the first tests begun by the Utah experiment station on the Nephi farm was planned to determine the relative return from cropping land to winter wheat continuously, every second year, one year in three, and two years in three. This test was conducted on four fifth-acre plats until the fall of 1907, when five tenth-acre plats were added, to allow the production of a crop under each condition each year. Since 1907, then, nine plats have been used.

The total yields per acre of the four fifth-acre plats obtained previous to 1908, the annual and total acre yields of all the plats from 1908 to 1913, and the total yields of the fifth-acre plats from 1904 to 1913, inclusive, are reported in Table XVI.

TABLE XVI.—*Annual and total yields of winter wheat obtained from continuous and alternate cropping and from growing one and two crops in three years at the Nephi substation, 1904 to 1913, inclusive.*

Frequency of crop.	Yield per acre of grain (bushels).								
	Total yield, 1904 to 1907.[1]	1908	1909	1910	1911	1912	1913	Total, 1908 to 1913.	Total, 1904 to 1913.
Continuous	60.20	13.41	14.58	7.80	5.70	6.00	4.50	51.99	112.19
Alternate	50.80	32.66	Fallow.	9.90	Fallow.	4.80	Fallow.	47.36	98.16
Do	....	Fallow.	2.50	Fallow.	28.00	Fallow.	1.83	32.33	....
Two crops in three years	25.10	32.74	13.42	Fallow.	23.60	3.90	Fallow.	73.66	98.76
Do	....	Fallow.	2.50	10.30	Fallow.	6.50	6.83	26.13	....
Do	....	21.16	Fallow.	8.20	8.10	Fallow.	2.33	39.79	....
One crop in three years	49.10	Fallow.	Fallow.	5.00	Fallow.	Fallow.	11.17	16.17	65.27
Do	....	Fallow.	3.50	Fallow.	Fallow.	10.80	Fallow.	14.30	....
Do	....	19.16	Fallow.	Fallow.	27.00	Fallow.	Fallow.	46.16	....

[1] Taken from Bulletin 112 of the Utah Agricultural Experiment Station.

The data presented in Table XVI are not wholly dependable, principally because winterkilling so reduced the yields in some years that their comparative value was almost wholly lost. The volunteer crops on the continuously cropped plat and the plat cropped two years in three were less affected by winterkilling than the sown crops, for the reason that they made more growth in the fall. As a result, uncontrollable factors, such as thin stands, weeds, etc., caused wide variations in the results, which did not indicate the true value of the methods employed.

The continuously cropped plat has not failed completely, however, in any year, even in the very dry years 1910 and 1911. In 1911, when there was very little winterkilling and good growing conditions prevailed, the continuously cropped plat and that cropped two years

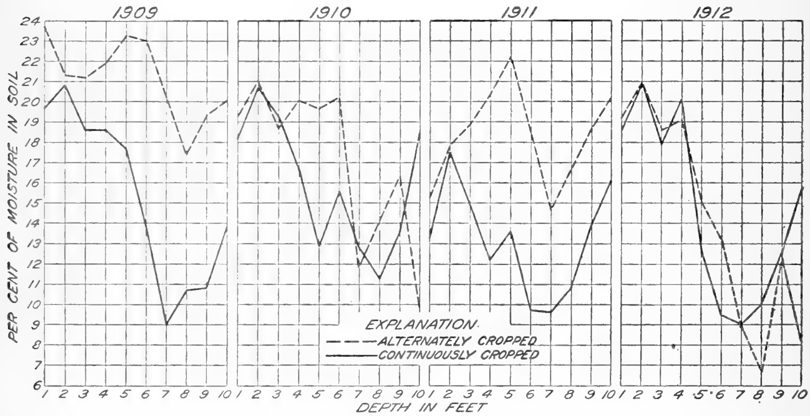

FIG. 20.—Graphs comparing the average percentage of moisture in each of the upper 10 feet of soil at the beginning of each season, as found on the alternately cropped and continuously cropped plats at the Nephi substation, 1909 to 1912, inclusive.

in three fell far below the others in yield. Under favorable conditions, it appears that the plats that have been fallow one or two years will give the best results. So much depends upon the time of planting, winterkilling, etc., however, that continuous cropping sometimes appears to be profitable, owing to the survival of volunteer grain.

The severe winterkilling in some years completely offsets the advantage of some plats in high soil-moisture content. This is well illustrated by figure 20, from which it will be seen that in 1909 the difference in moisture content of the continuously cropped plat and the alternately cropped plat was greatly in favor of the latter at the beginning of the season, yet, because of a better stand, due to the volunteer grain, the continuously cropped plat yielded nearly seven times as much as the other, as is shown in Table XVI. In 1910 the differences, though less marked, were much the same as those of

the previous year. In 1911, however, under favorable conditions, the yields were consistent with the soil moisture. In 1912 there was little difference either in moisture or yield.

These results indicate that where a good stand is obtained in the fall and little winterkilling follows, the crops following fallow will yield more than those grown on continuously cropped land. To determine the relative value of the two systems of cropping, the cost of growing a crop and of maintaining a fallow must also be taken into consideration. In the vicinity of Nephi, the cost of growing and harvesting wheat is about $3 per acre more than the cost of maintaining a fallow throughout the year. This extra cost must be charged against the crop which is obtained in alternate years on the continuously cropped land. On this basis, the 14 bushels greater yield per acre in 10 years from the land continuously cropped have been obtained at a cost of $15, for the $3 extra cost has been incurred five times in the 10 years. This extra cost is greater than the value of the increased yield, which is further evidence that alternate cropping and fallowing is preferable to continuous cropping to wheat.

INTERTILLED CROPS COMPARED WITH FALLOW IN ALTERNATION WITH WINTER WHEAT.

The most direct attempt made at the Nephi substation to find a successful substitute for the alternation of a cereal crop and summer fallow has been in a simple rotation in which winter wheat was grown after fallow and after corn, peas, and potatoes in rotation. As this test has been in progress since 1908 sufficient data have been accumulated to justify consideration at this time. An outline of the rotation is given in Table XVII.

TABLE XVII.—*Rotation of intertilled crops and fallow alternating with wheat.*

Plat.	1908	1909	1910	1911	1912	1913
12B	Wheat	Fallow	Wheat	Fallow	Wheat	Fallow.
13B	...do	Corn	...do	Peas	...do	Potatoes.
14B	...do	Potatoes	...do	Corn	...do	Peas.
15B	...do	Peas	...do	Potatoes	...do	Corn.
12C	Fallow	Wheat	Fallow	Wheat	Fallow	Wheat.
13C	Potatoes	...do	Corn	...do	Peas	Do.
14C	Peas	...do	Potatoes	...do	Corn	Do.
15C	Corn	...do	Peas	...do	Potatoes	Do.

TREATMENT OF PLATS.

The four plats which had grown wheat were plowed in the fall of each year to a uniform depth of about 8 inches. The land then received no cultivation until the next spring, when it was double disked or harrowed sufficiently to destroy all weeds and make a good fallow or a good seed bed. The plat to be summer-fallowed was treated normally in the spring and throughout the summer. The

corn, peas, and potatoes were planted in rows far enough apart to permit intertillage, the cultivation during the summer being practically the same for the cropped and the fallow plats. The corn and peas were drilled in rows about 35 inches apart, while the potatoes were dropped behind a plow in hills 24 inches apart in rows 3 feet apart.

After the crops were harvested from these plats in the usual manner in the fall, winter wheat was sown on them and on the fallow plat at

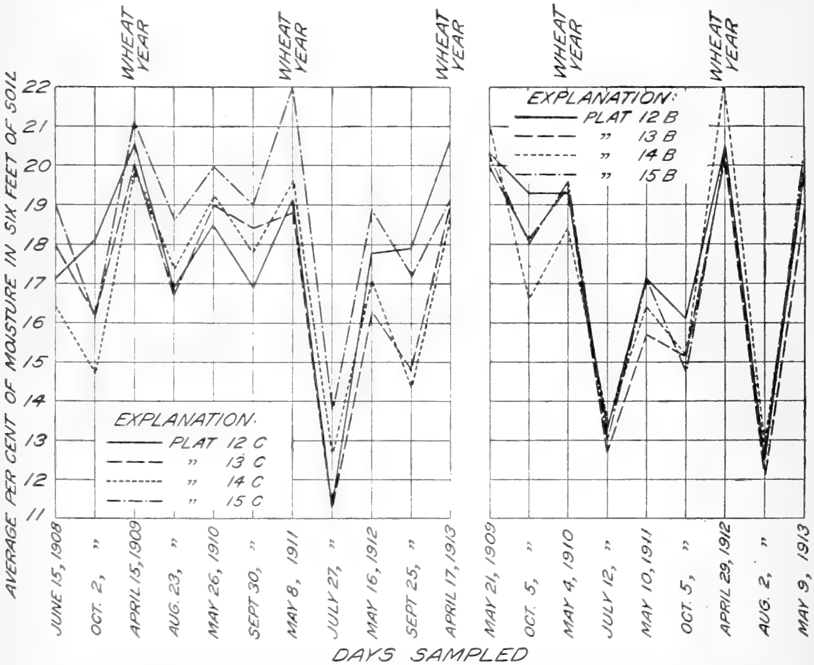

FIG. 21.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning and at the end of each season, as found in the rotation experiments at the Nephi substation, 1908 to 1913, inclusive.

the same rate and on the same date. The subsequent treatment of the plats was identical in every respect.

MOISTURE CONTENT OF THE SOIL.

Soil-moisture determinations were made on the plats in the rotation during each year of the test. The plats growing wheat were sampled at the beginning, in the middle, and at the end of each season, while the other plats were sampled about once a month during the season. The moisture content of each foot of soil to a depth of 6 feet was determined in the usual manner.

The results indicate that there was very little difference in the moisture content of any foot of soil on the different plats. The varia-

tions favored one plat one year and another plat the next, changing so frequently that no one plat had any marked advantage. The average moisture content in the first 6 feet of soil on all plats in the rotation at the beginning and end of each season from 1908 to 1913, inclusive, is shown graphically in figure 21. It will be noted that the average moisture content of the plats was usually surprisingly uniform, and that no great difference existed in any case. During the wheat years the moisture content of all plats was reduced to a minimum, but during the alternate years the moisture content remained reasonably constant.

YIELDS OBTAINED.

The yields of the various crops obtained in these rotation experiments are presented in Table XVIII. No attention should be paid to the yields of wheat from the "B" plats in 1908, as they were occupied by four different varieties in the regular varietal test, and varietal differences probably affected the yields. In all other years the same variety was used on all plats.

TABLE XVIII.—*Yields obtained in tests of winter wheat* [1] *in alternation with fallow and with corn, peas, and potatoes in rotation at the Nephi substation, for the years 1908 to 1913, inclusive.*

[Yields per acre (wheat and potatoes in bushels, corn and peas in pounds).]

Plat.	1908		1909		1910	
	Crop.	Yield.	Crop.	Yield.	Crop.	Yield.
12B	Wheat	27.50	Fallow		Wheat	13.7
13B	do	25.83	Corn (fodder)	1,240	do	19.3
14B	do	30.16	Potatoes	84.7	do	17.2
15B	do	22.66	Peas (vines)	1,050	do	18.3
12C	Fallow		Wheat	4.66	Fallow	
13C	Potatoes	42.50	do	2.50	Corn (fodder)	40
14C	Peas {Vines Peas {Seed	1,080 220	do	2.16	Potatoes	7.35
15C	Corn {Fodder Corn {Grain	630 17.5	do	6.50	Peas (vines)	35

Plat.	1911		1912		1913	
	Crop.	Yield.	Crop.	Yield.	Crop.	Yield.
12B	Fallow		Wheat	14.7	Fallow	
13B	Peas	Failure.	do	17.8	Potatoes	34.5
14B	Corn (fodder)	40	do	18.8	Peas {Vines Peas {Seed	95 20
15B	Potatoes	4	do	18.7	Corn {Fodder Corn {Unshelled grain	550 200
12C	Wheat	30	Fallow		Wheat	2.0
13C	do	28.5	Peas {Vines Peas {Seed	225 90	do	4.2
14C	do	32.1	Corn (fodder)	1,420	do	4.4
15C	do	29.5	Potatoes	32.4	do	4.2

[1] In 1908 the wheat plats were a part of the regular varietal test, so that the results for that year should be disregarded. The varieties were as follows: On plat 12B, Crimean (C. I. No. 1433); plat 13B, Crimean (C. I. No. 1435); plat 14B, Crimean (C. I. No. 1436); and on plat 15B, Koffoid (C. I. No. 2997). In 1909 the last-named variety was grown on all plats, while in 1910 and succeeding years the Turkey variety (C. I. No. 2998) was used.

Wheat after corn gave the highest yield obtained in 1909, while wheat after fallow yielded better than wheat after either potatoes or peas. The yields of 1909, however, were extremely low because of excessive winterkilling. Consequently they would be practically worthless if they were not relatively the same as those obtained in later years. In 1910 wheat after fallow yielded much less than wheat after any intertilled crop. In 1911 wheat after potatoes gave the highest yield, while there was little difference in the yields of the other plats. Wheat after fallow again gave the lowest yield in 1912 and 1913. A summary of the wheat yields obtained in this test for the five years from 1909 to 1913, inclusive, is given in Table XIX.

TABLE XIX.—*Annual and average yields of winter wheat obtained after corn, potatoes, peas, and fallow, at the Nephi substation, for the years 1909 to 1913, inclusive.*

Rotation.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
Wheat after corn	6.50	19.30	28.50	18.80	4.40	15.50
Wheat after potatoes	2.50	17.20	32.10	18.70	4.20	14.94
Wheat after peas	2.16	18.30	29.50	17.80	4.20	14.39
Wheat after fallow	4.66	13.10	30.00	14.70	2.00	12.89

Table XIX shows that the average yield of wheat for five years was less after fallow than after corn, potatoes, or peas.

A summary of the total crop yields of all plats since the test began is given in Table XX, where it will be noticed that plats 12B and 12C, wheat after fallow, have given the lowest total returns per acre.

TABLE XX.—*Summary of total crop yields from the intertillage and fallow rotation plats at the Nephi substation, 1908 to 1913, inclusive.*

Years and plats.	Total yields per acre.					
	Wheat.	Corn.		Peas.		Potatoes.
		Grain.	Fodder.	Seed.	Hay.	
	Bus.	*Bus.*	*Lbs.*	*Lbs.*	*Lbs.*	*Bus.*
1909 to 1913:						
12B	28.40					
13B	37.10	None.	1,240	Failure.	Failure.	34.50
14B	36.00	None.	40	20	95	84.70
15B	37.00	2.9	550	None.	1,050	4.00
1908 to 1913:						
12C	36.66					
13C	35.20	None.	40	90	225	42.50
14C	38.66	None.	1,420	220	1,080	7.35
15C	40.20	17.5	630	None.	35	32.40

Table XX shows that the wheat yields on the "B" series are greatly in favor of the plats which produced an intertilled crop in alternate years, the differences in acre yields varying from 8 to 9 bushels. In addition to yielding as much wheat as plat 12C, the

other plats on the "C" series have given good yields of the intertilled crops. From these results it appears that the production of intertilled crops had some effect on the soil which was beneficial to the following wheat crop. It is difficult to determine the nature of this effect, but that it was present can not be doubted.

The intertilled crops were sometimes unprofitable, in some instances total failures, but the losses thus accruing were offset by profitable yields in more favorable seasons. The cost of growing these crops was somewhat higher than the cost of maintaining fallow, but the yields of the intertilled crops and the higher wheat yields following made up for this difference in cost. It is quite impossible to determine with any great degree of satisfaction the relative value of these rotations, since the total yields of some of the intertilled crops were so small, and because the production of such crops on the dry lands of the Great Basin is practically unheard of, there is no standard for estimating values. Perhaps the greatest value that will come from the results of the above experiment will be to point out the possibilities of such a rotation and to encourage greater effort in the development of better varieties of intertilled crops or better methods of producing the varieties now used.

SUMMARY.

The Nephi substation is located in the Juab Valley, in the eastern part of Juab County, in central Utah. The soil in this locality is very deep. It ranges from clay to sandy loam. In the virgin state it is covered with a dense growth of black sagebrush.

The average annual precipitation in the Juab Valley during the past 16 years was 13.40 inches. During the progress of the experiments reported herein (1908 to 1913), the precipitation in 1908 and 1909 was above normal, while in 1910, 1911, 1912, and 1913 it was below normal. The winter and spring precipitation is the heaviest of the year. The rains of summer have been small and consequently of little value to the growing crops.

The average evaporation at the Nephi substation during the six months from April to September, inclusive, has been about 45 inches. The average wind velocity for any one day has not exceeded 10 miles per hour. Protracted hot winds are unknown. Only two months of the year, July and August, have been free from frost. Normally, however, there are from 90 to 100 days in the frost-free period, extending from about June 15 to September 15.

Most of the experiments reported upon have been in progress since 1908. A few are of longer duration, while some were begun as late as 1911. The tests have dealt with stubble treatment immediately after harvest; time and depth of plowing; cultivation of

fallow; seeding, cultivation, and harvesting the crop; frequency of cropping; and diversity of crops in rotation.

The tests dealing with stubble treatment immediately after harvest were begun in the fall of 1911. The results so far obtained are not conclusive enough to warrant publication.

The average results for five years, 1909 to 1913, inclusive, show that spring plowing was better than fall plowing for moisture conservation, in yield of grain, and in cost of producing the crop. Spring plowing gave an average yield of 18.5 bushels per acre, as compared with 16.8 bushels for fall plowing. Owing to this difference in yield and the lower cost of producing the crop, spring plowing gave a net acre profit of $3.03 more than fall plowing.

The results of five years show that there was no advantage in deep plowing or subsoiling over shallow plowing so far as moisture conservation is concerned. There was no material difference in the yields obtained from plats plowed at different depths, varying from 5 to 18 inches. The highest average yield was obtained from plats plowed 10 inches deep, and the lowest average yield was from the plats subsoiled 18 inches deep, while the 5-inch plowing yielded higher than the 15-inch subsoiling.

One year's results from a test of deep fall plowing and shallow spring plowing compared with shallow fall plowing and deep spring plowing show no difference in soil moisture and but slight difference in yield.

The results of five years' experiments on fall-plowed fallow show that the moisture of the cultivated plats remained practically the same throughout the season, while that of the uncultivated plats rapidly declined, until by fall it was reduced to a comparatively low point. It is probable that weeds and volunteer grain were important factors in this loss of moisture. The average acre yield of the cultivated plats was 17 bushels, as compared with 13 bushels on the uncultivated plats.

The results of one season on spring-plowed fallow show no difference in the moisture content of the plats cultivated or not cultivated. The yields, 11.9 and 9.5 bushels per acre, favor the noncultivated plat.

The results of 10 years show no correlation between the time of sowing winter wheat and the yield, but the best yields have usually been obtained from plats seeded between September 1 and October 15. There was no significant difference between the average moisture content of the plats for any one or for all years. The chief problem in the time-of-seeding tests of winter wheat now seems to be a mechanical one involving some improvement of the machinery used in seeding. It is believed that this will obviate the necessity of

waiting for rain before seeding, thus permitting early seeding, which seems desirable, and allowing the crop time enough to make a fair growth before the advent of winter. Late planting is often followed by much winterkilling, which completely offsets the value of any tillage method used in preparing the land and of the quantity of moisture stored in it.

The average result of five years' tests shows no difference in the yields of winter wheat seeded at different depths. The yields were greatly influenced by conditions at seeding time.

The ordinary drilling of winter wheat has given more profitable yields than broadcasting or cross drilling.

The results of three years' experiments show that winter wheat sown at the rate of 4 to 5 pecks per acre is more profitable than when sown at 3 pecks per acre, the rate ordinarily used on the dry lands of the Great Basin.

The average yields of five years favor no spring cultivation of winter wheat. The noncultivated plats yielded 17.05 bushels, as compared with 15.99 bushels from those cultivated. There was no apparent difference in the moisture content of the plats. A test made in the spring of 1913 showed that 11.54 per cent of the plants were killed by one harrowing. This loss offsets all benefits that might have come from harrowing.

The results of four years favor harvesting when the grain is in the hard-dough stage.

Where a good stand was obtained and little winterkilling followed, winter wheat after fallow yielded more than winter wheat on continuously cropped land. This depended largely upon the season, however, and the continuously cropped plat, owing to volunteer grain, yielded as well or better than other plats in the test in seasons of much winterkilling.

The average acre yield of winter wheat for five years was less after fallow than after corn, potatoes, or peas.

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